AN-NAJAH NATIONAL UNIVERSITY

FACULTY OF ENGINEERING

ELECTRICAL ENGINEERING DEPARTMENT

# Control Systems Lab

## (10641441/65540)

Student Manual


Last Revised by:

**Inst. Read Jaber**

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Eng. **Ibtehal Zaid**


2018/2019

**An-Najah National University**
**Faculty of Engineering and IT**

**جامعة النجاح الوطنية**
**كلية الهندسة وتكنولوجيا المعلومات**

## Department Name : Electrical Engineering Department
## Course Name: Control Systems Lab        Number :(10641441/65540)
## Report Grading Sheet

| | |
|---|---|
| Instructor Name: Raed Jaber | Experiment #: |
| Academic Year: 2018/2019 | Performed on: |
| Semester: | Submitted on: |

**Lab day**:        **Lab Time:**

| **Students:** | |
|---|---|
| 1- | 2- |
| 3- | 4- |
| 5- | 6- |

**Report's Outcomes**

| | | | | |
|---|---|---|---|---|
| ILO __ =(  ) % | ILO __ =(  ) % | ILO __ =(  ) % | ILO __ =(  ) % | ILO __ =(  ) % |

| Evaluation Criterion | Grade | Points |
|---|---|---|
| **Abstract**<br>answers of the questions: "What did you do? How did you do it? What did you find?" | | |
| **Introduction**<br>Sufficient, Clear and complete statement of objectives. | 1 | |
| **Theory**<br>Presents sufficiently the theoretical basis. | 1 | |
| **Apparatus/ Procedure**<br>Apparatus sufficiently described to enable another experimenter to identify the equipment needed to conduct the experiment. Procedure sufficiently described. | 2 | |
| **Experimental Results and Calculations**<br>Results analyzed correctly. Experimental findings adequately and specifically summarized, in graphical, tabular, and/or written form. | 2 | |
| **Discussion**<br>Crisp explanation of experimental results. Comparison of theoretical predictions to experimental results, including discussion of accuracy and error analysis in some cases. | | |
| **Conclusions and Recommendations**<br>Conclusions summarize the major findings from the experimental results with adequate specificity. Recommendations appropriate in light of conclusions. Correct grammar. | 2 | |
| **References**<br>Complete and consistent bibliographic information that would enable the reader to find the reference of interest. | | |
| **Appendices**<br>Appropriate information, organized and annotated. Includes all calculations and raw data Sheet. | 1 | |
| **Appearance**<br>Title page is complete, page numbers applied, content is well organized, correct spelling, fonts are consistent, good visual appeal. | 1 | |
| **Total** | 10 | |

# Table of Contents

| Department of Electrical Engineering | |
|---|---|
| **Control systems lab (10641441)** | |
| **Total Credits** | **1** |
| **major compulsory** | |
| **Prerequisites** | P1 : Control Systems (10641343)<br>P11Synch. : Control Systems (10641343) |
| **Course Contents** | |
| Control circuit using contactors<br>Introduction to pneumatic system<br>Introduction to PLC<br>Introduction to controller system<br>Motor control<br>Basic electrically controlled pneumatic circuits<br>PLC programming<br>Open-loop & Closed loop system<br>Star-Delta Starter & speed control of three phase asynchronous motor<br>PLC counters<br>Type of controllers<br>Pneumatic counters | |

| | **Intended Learning Outcomes (ILO's)** | **Student Outcomes (SO's)** | **Contribution** |
|---|---|---|---|
| 1 | An ability to apply knowledge of different usage of contactors in the three phase systems, and Pneumatics Trainer, to identify the various system components, timers and Counters in pneumatics circuits and Control circuit using contactors | A | 40 % |
| 2 | An ability to use useful techniques of circuits using the types of controllers, and to study the deferent types of controllers, P, PI, PD, and to be able to build Star-Delta Starter, and to design speed Control of three Phase Asynchronous Motor and PLC-pr | C | 40 % |
| 3 | An ability to design different circuits of the three phase system, and some PLC programs. | B | 20 % |

**Textbook and/ or Refrences**

Automatic Control Lab Manual

| **Assessment Criteria** | **Percent (%)** |
|---|---|
| Reports | 50 % |
| Laboratory Work | 25 % |
| Final Exam | 25 % |

**Course Plan**

| **Week** | **Topic** |
|---|---|
| 1 | Introduction & Safety instructions |

| | |
|---|---|
| 2 | Control circuit using contactors |
| 3 | Introduction to pneumatic system |
| 4 | Introduction to PLC |
| 5 | Introduction to controller system |
| 6 | Motor control |
| 7 | Basic electrically controlled pneumatic circuits |
| 8 | Timers and counters on PLC |
| 9 | Open-loop & Closed loop system |
| 10 | Star-Delta Starter & speed control of three phase asynchronous motor |
| 11 | Timers and Counters in Pneumatics Circuits |
| 12 | Traffic light simulation on PLC |
| 13 | Type of controllers |
| 14 | Final Exam |

# Lab Safety Guidelines

1) Be familiar with the electrical hazards associated with your workplace.

2) You may enter the laboratory only when authorized to do so and only during authorized hours of operation.

3) Be as careful for the safety of others as for yourself. Think before you act, be tidy and systematic.

4) Avoid bulky, loose or trailing clothes. Avoid long loose hair.

5) Food, beverages and other substances are strictly prohibited in the laboratory at all times. Avoid working with wet hands and clothing.

6) Use extension cords only when necessary and only on a temporary basis.

7) Request new outlets if your work requires equipment in an area without an outlet.

8) Discard damaged cords, cords that become hot, or cords with exposed wiring.

9) Before equipment is energized ensure, (1) circuit connections and layout have been checked by a laboratory technician and (2) all colleagues in your group give their assent.

10) Know the correct handling, storage and disposal procedures for batteries, cells, capacitors, inductors and other high energy-storage devices.

11) Experiments left unattended should be isolated from the power supplies. If for a special reason, it must be left on, a barrier and a warning notice are required.

12) Equipment found to be faulty in any way should be reported to the laboratory technician immediately and taken out of service until inspected and declared safe.

13) Never make any changes to circuits or mechanical layout without first isolating the circuit by switching off and removing connections to power supplies.

14) Know what you must do in an emergency, i.e. Emergency Power Off

15) For pneumatic trainer

a-Do not attempt to block compressed air line or fitting with finger or hands.

b- Tubes, components, and other devices that are not part of the trainer should not be used with the trainer because they may burst and injure the operator.

c- Leaks on pneumatic equipment should never be tightened while there is pressure in the system. Stop the air supply release the pressure then repair the leak

d-Never place the pneumatic cylinders in a position where they may become wedged or confined between rigid parts of the trainer. Damage to the operator and the unit could result.

e-. Never release compressed air near or in body cavities.

f- Safety glasses with side shields should always be worn when working with compressed air.

j- Keep, the trainer; and, its components clean and in good working order. .Any equipment should not be used until further inspection indicates they are safe for operation.

h-Noise can be damaging to the ears at certain levels. Avoid continuous exposure to air release. Reduce released compressed air noise and/or wear ear protectors.

**Electrical Emergency Response**

The following instructions provide guidelines for handling two types of electrical emergencies:

1. ***Electric Shock***:

When someone suffers serious electrical shock, he or she may be knocked unconscious. If the victim is still in contact with the electrical current, immediately turn off the electrical power source. If you cannot disconnect the power source, depress the Emergency Power Off switch.


**IMPORTANT:**

Do not touch a victim that is still in contact with a live power source; you could be electrocuted.

Have someone call for emergency medical assistance immediately. Administer first-aid, as appropriate.

2. ***Electrical Fire:***

If an electrical fire occurs, try to disconnect the electrical power source, if possible. If the fire is small and you are not in immediate danger; and you have been properly trained in fighting fires, use the correct type of fire extinguisher to extinguish the fire. When in doubt, push in the Emergency Power Off button.

NEVER use water to extinguish an electrical fire.

# Lab Report Format

Following the completion of each laboratory exercise, a report must be written and submitted for grading. The purpose of the report is to completely document the activities of the design and demonstration in the laboratory. Reports should be complete in the sense that all information required to reproduce the experiment is contained within. Writing useful reports is a very essential part of becoming an engineer. In both academic and industrial environments, reports are the primary means of communication between engineers.

There is no one best format for all technical reports but there are a few simple rules concerning technical presentations which should be followed. Adapted to this laboratory they may be summarized in the following recommended report format:

- ABET Cover Page
- Title page
- Introduction
- Experimental Procedure
- Experimental Data
- Discussion
- Conclusions

Detailed descriptions of these items are given below.

## Title Page:

The title page should contain the following information

- Your name
- ID
- Experiment number and title
- Date submitted
- Instructors Name

## Introduction:

It should contain a brief statement in which you state the objectives, or goals of the experiment. It should also help guide the reader through the report by stating, for example, that experiments were done with three different circuits or consisted of two parts etc. Or that additional calculations or data sheets can be found in the appendix, or at the end of the report.

## The Procedure

It describes the experimental setup and how the measurements were made. Include here circuit schematics with the values of components. Mention instruments used and describe any special measurement procedure that was used.

## Results/Questions:

This section of the report should be used to answer any questions presented in the lab hand-out. Any tables and /or circuit diagrams representing results of the experiment should be referred to and discussed / explained with detail. All questions should be answered very clearly in paragraph form. Any unanswered questions from the lab hand-out will result in loss of points on the report.

The best form of presentation of some of the data is graphical. In engineering presentations a figure is often worth more than a thousand words. Some simple rules concerning graphs and figures which should always be followed. If there is more than one figure in the report, the figures should be numbered. Each figure must have a caption following the number. For example, *"Figure 1.1:DSB-SC "* In addition, it will greatly help you to learn how to use headers and figures in MS Word.

## The Discussion

It is a critical part of the report which testifies to the student's understanding of the experiments and its purpose. In this part of the report you should compare the expected outcome of the experiment, such as derived from theory or computer simulation, with the measured value. Before you can make such comparison you may have to do some data analysis or manipulation.

When comparing experimental data with numbers obtained from theory or simulation, make very clear which is which. It does not necessarily mean that your experiment was a failure. The results will be accepted, provided that you can account for the discrepancy. Your ability to read the scales may be one limitation. The value of some circuit components may not be well known and a nominal value given by the manufacturer does not always correspond to reality. Very often, however, the reason for the difference between the expected and measured values lies in the experimental procedure or in not taking into account all factors that enter into analysis.

## Conclusion:

A brief conclusion summarizing the work done, theory applied, and the results of the completed work should be included here. Data and analyses are not appropriate for the conclusion.

***Notes***

Typed Reports are required. Any drawings done by hand must be done with neatness, using a straightedge and drawing guides wherever possible.
**Freehand drawings will not be accepted.**

## Experiment Groups

| | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 | Group 8 |
|---|---|---|---|---|---|---|---|---|
| Week 1 | Introduction to Lab Devices & Safety Instructions | | | | | | | |
| Week 2 | Exp 1 | Exp 1 | Exp 2 | Exp 2 | Exp 3 | Exp 3 | Exp 4 | Exp 4 |
| Week 3 | Exp 2 | Exp 2 | Exp 3 | Exp 3 | Exp 4 | Exp 4 | Exp 1 | Exp 1 |
| Week 4 | Exp 3 | Exp 3 | Exp 4 | Exp 4 | Exp 1 | Exp 1 | Exp 2 | Exp 2 |
| Week 5 | Exp 4 | Exp 4 | Exp 1 | Exp 1 | Exp 2 | Exp 2 | Exp 3 | Exp 3 |
| Week 6 | Exp 5 | Exp 5 | Exp 6 | Exp 6 | Exp 7 | Exp 7 | Exp 8 | Exp 8 |
| Week 7 | Exp 6 | Exp 6 | Exp 7 | Exp 7 | Exp 8 | Exp 8 | Exp 5 | Exp 5 |
| Week 8 | Exp 7 | Exp 7 | Exp 8 | Exp 8 | Exp 5 | Exp 5 | Exp 6 | Exp 6 |
| Week 9 | Exp 8 | Exp 8 | Exp 5 | Exp 5 | Exp 6 | Exp 6 | Exp 7 | Exp 7 |
| Week 10 | Exp 9 | Exp 9 | Exp 10 | Exp 10 | Exp 11 | Exp 11 | Exp 12 | Exp 12 |
| Week 11 | Exp 10 | Exp 10 | Exp 11 | Exp 11 | Exp 12 | Exp 12 | Exp 9 | Exp 9 |
| Week 12 | Exp 11 | Exp 11 | Exp 12 | Exp 12 | Exp 9 | Exp 9 | Exp 10 | Exp 10 |
| Week 13 | Exp 12 | Exp 12 | Exp 9 | Exp 9 | Exp 10 | Exp 10 | Exp 11 | Exp 11 |
| Week 14 | Review & Discussion | | | | | | | |
| Week 15 | Final Practical Exam | | | | | | | |

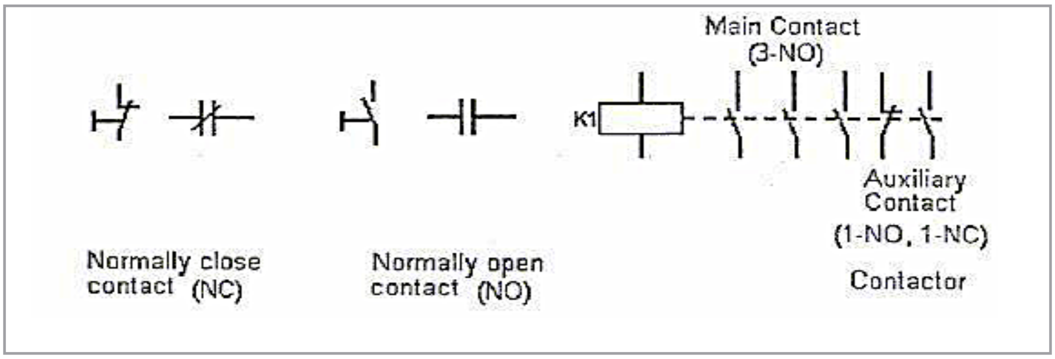
# Electrical Engineering Department
# Control Lab
# Experiment #1
# Control circuit using contactors

**Objectives**

1. To study the basic concepts and operation of NO, NC, AND, OR and contactor latching.
2. To study the sequential circuit, reversing control with sequential circuits.

**Some definitions**

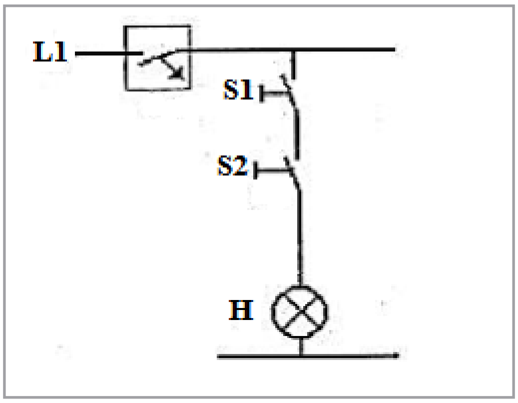
In the following we defined some symbols of switches and contactors:




**Experimental Procedure**

A) **AND operation**

1. Connect the circuit shown in Fig(1) and complete the truth Table(1).



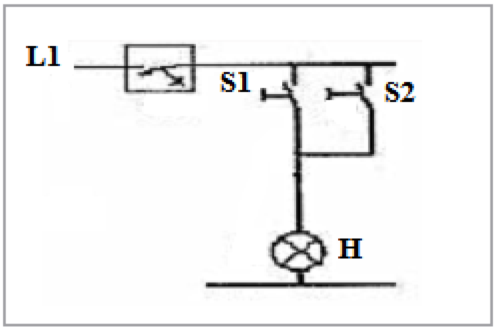

**Fig(1)**

| S1 | S2 | H |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

**Table(1)**

## B) OR operation

1. Connect the circuit shown in Fig(2) and complete the truth Table(2).

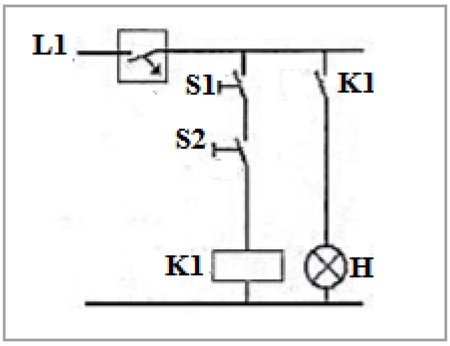



| S1 | S2 | H |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Fig(2) Table(2)

## C) AND-OR circuit with contactors

1. Connect the circuit shown in Fig(3) describe how it works and write its truth table.

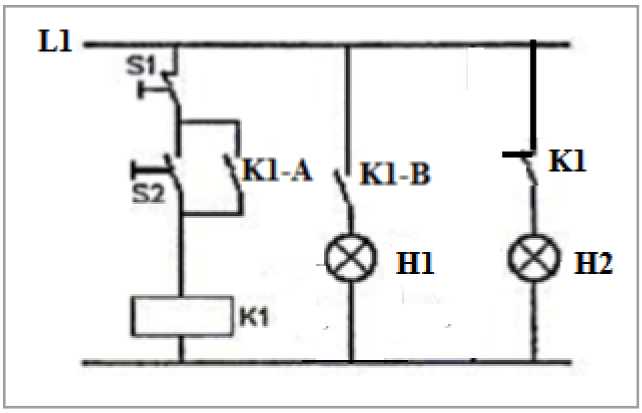


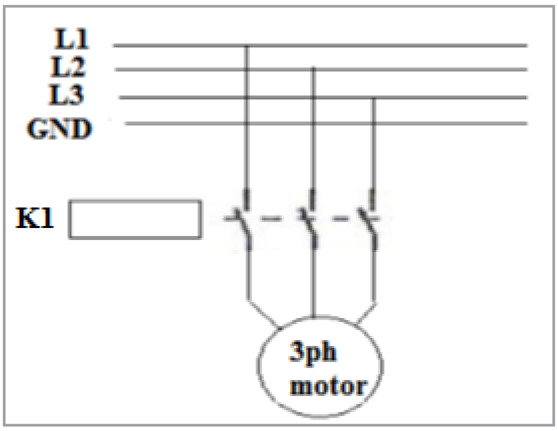

Fig(3)

2. Repeat step one but connect S1, S2 parallel.

## D) Self holding of contactor (latching)

1. Connect the circuit diagram shown in Fig(4).
2. Then use the required changes to the control circuit in Fig(4) to solve Exercise#1.




Fig(4)

**Exercise # 1**

Construct a wiring circuit for a lamp to be light from 2 positions and switch off from 3 positions, use push buttons and latch in your diagram. (use two switches NO and three switches NC and one contactor).

**All the following exercises must be assembled and tested in the lab.**

**Exersise#2: Sequential circuit**

Construct circuit diagram for a machine has two motors, motor number 2 will not work if motor number 1 is not working. (Note, you have to use three switches one for shutdown, the second to turn machine 1 on and the third to turn machine two on) and use two contactors.

**Exercise# 3**

Design a control system for three lamps so that when one of the lamps has been switched on, no other lamp can be switched on. Only after pressing the switch off, it is possible to switch on one of the three lamps on again. (use three contractors).

# Electrical Engineering Department
# Control Lab
# Experiment #2
# Introduction to pneumatic systems

**Objectives:**

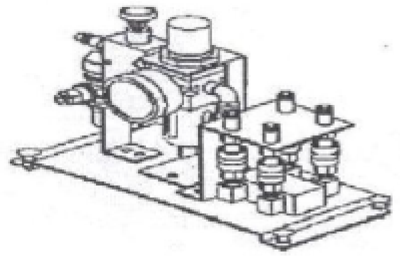
1. To become familiar with the Pneumatics Trainer.
2. To identify the various system components.
3. To be aware of the safety rules to follow when using Pneumatics Trainer.
4. To investigate a basic pneumatic circuit.
5. To learn about pneumatic power characteristics, applications, advantages and disadvantages.

**Introduction**

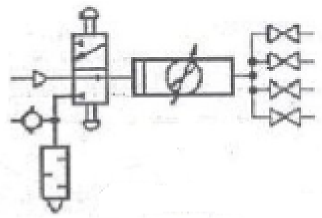
Identifying the Trainer Components:

### 1. Conditioning unit

It consists of a main shutoff valve, filter, pressure regulator, pressure gauge and a 4-port manifold as shown in Fig(1).



**Conditioning unit P/N(6411)**

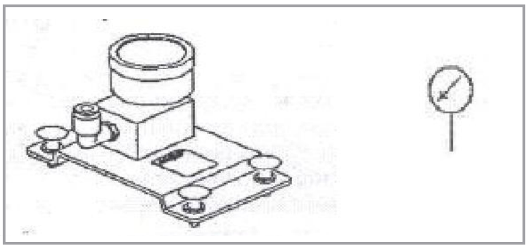


**Simplified symbol**

**Fig(1)**

### 2. Pressure gauge

Pressure gauges convert pressure into a dial reading, Fig(2) show pressure gauge and their symbol.



**Fig(2): Pressure gauges**

## 3. Valve

Valves are used to control flow and/or direction. Some valves have two ports others have more. Fig (3) show some types of valves used in the trainer.

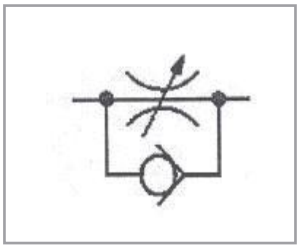
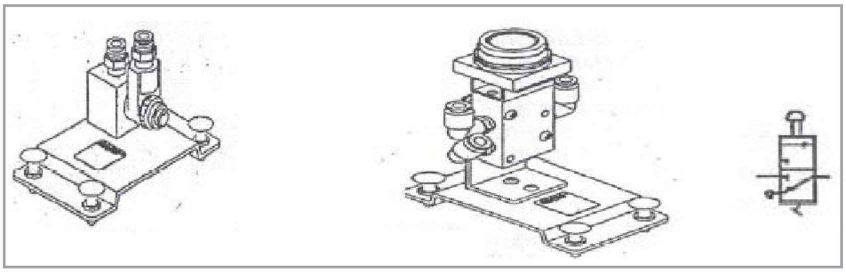


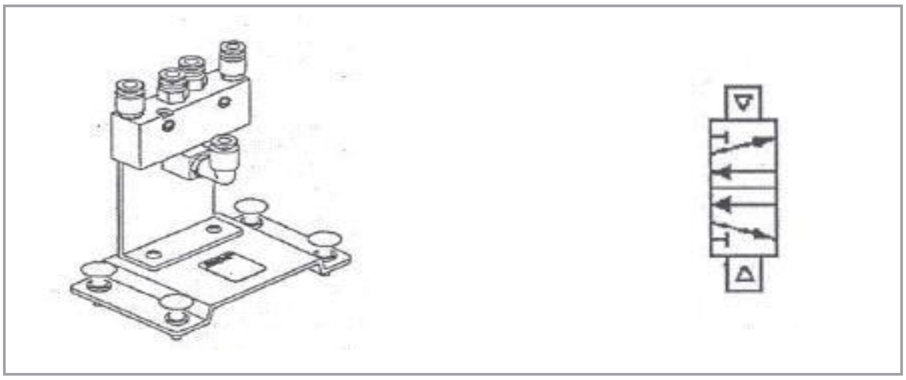
**Fig (3-a): Flow control valve.**



**Fig(3-b):Directional valve-:push-bottom operated.**

## 4. Directional valve, double air pilot operated

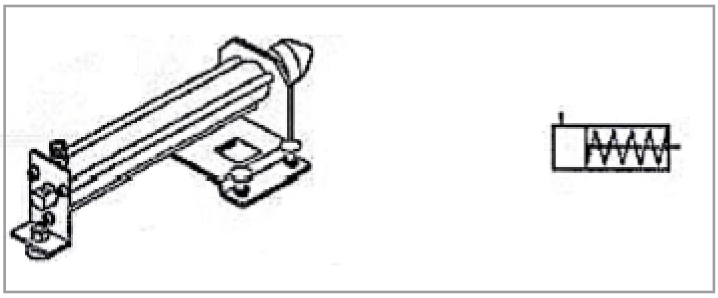
The operation of a double-piloted,4-way,2-position directional control valve is illustrated in Fig (3-c).When pilot port A is pressurized, ports 1 and 2 are interconnected through the valve, supplying the branch circuit with compressed air. Ports 3 and 4 are also interconnected through the valve, connecting the branch circuit to atmosphere. When the spool is shifted by pressurizing pilot port 6, ports 1 and 4 are interconnected to supply the branch circuit with compressed air. Compressed air is exhausted from the branch circuit to atmosphere through interconnected ports 2 and 3. Pilot-operated valves can have manual overrides to move the spool without pilot pressure for setup troubleshooting.



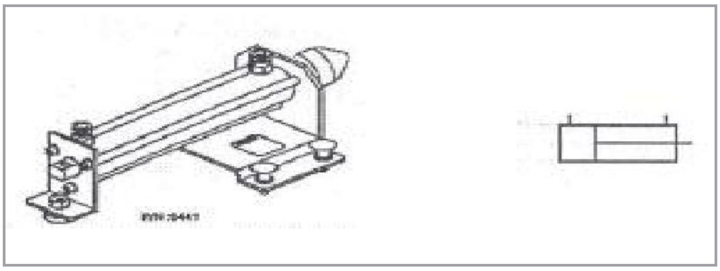
**Fig( 3-C): Directional valve, double air pilot operated.**

## 5. Cylinders and load device

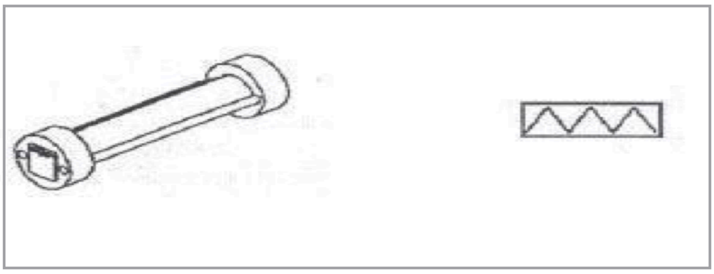
Cylinders are actuators that convert fluid energy into linear mechanical power. One of the cylinders of your trainer is a double-acting type because it works in both the extension and retraction stroke of the piston rod, the other cylinder is a spring return-type. The load device is used to measure the force generated by the cylinders. Fig (4) shows the type used in the lab.



Fig(4-a):Single Acting Cylinder.



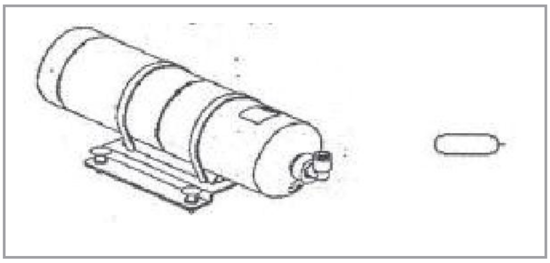
Fig(4-b):Single end rood double acting cylinder.



Fig(4-c):Double end rood acting cylinder.

## 6. Accumulator

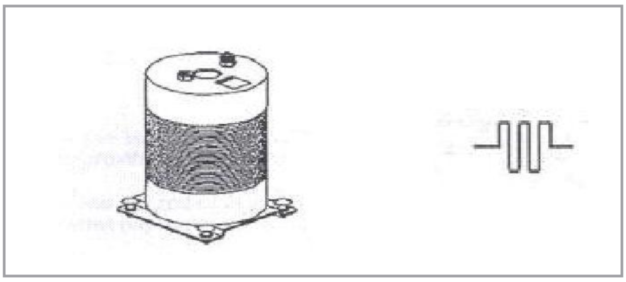
Accumulators are receivers that are used to store pressurized: air in a pneumatic system as shows in Fig(5).



Fig(5):Accumulator.

**7. Long line device**

The long line device is used to generate friction in a circuit as shows in Fig(6).



**Fig(6): Long line device**

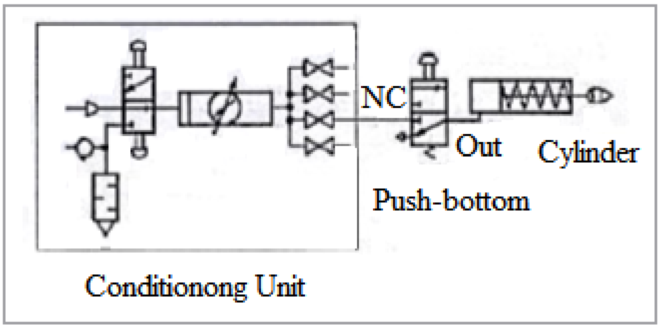
**8. Pneumatic Motor**

Pneumatic motors convert fluid energy into mechanical rotational energy. When a pressure differential is created within a pneumatic motor the higher pressure air expands. This expanding air acts upon the internal surfaces of the motor to cause the motor output shaft to turn.

**<u>Experimental procedure:</u>**

**<u>A) Fundamental Pneumatic Circuit</u>**

1. Construct the circuit shown in Fig(7).




**Fig(7)**

2. On the Conditioning Unit, open the main shutoff valve and the branch shutoff valve adjust the regulator to set the pressure at 300kPa.

➔ Does the rod of the cylinder extend when the button is pressed? What happens to the cylinder when the button is released? Explain

**<u>Exercise#1</u>**

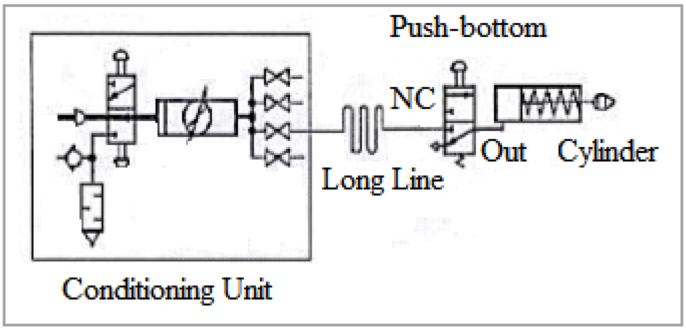
Construct and implement pneumatic circuit in which cylinder cannot extended until two switches pushed as:

a) AND operation.

b) OR operation.

**B) Air conditioning and distributing equipment**

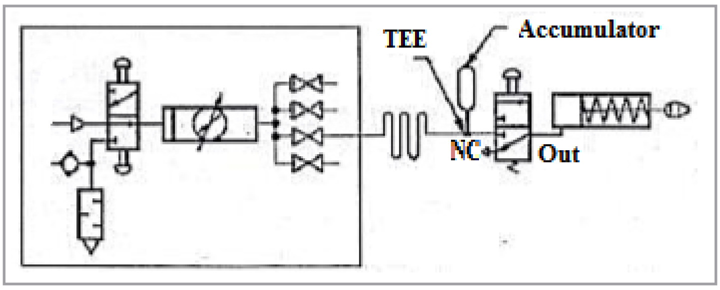
1. Connect the circuit shown in Fig(8).




**Fig(8)**

2. Open the main shutoff valve and set the pressure regulator at 300 kPa on the regulated pressure gauge.
3. Open the branch shut off valve. Push the button on the directional control valve and observe the time taken for a full extension of the cylinder rod Wait a few seconds and repeat.

4. Close the shut off valves and modify the circuit to add an accumulator in the proximity of the cylinder as shown in Fig(9).




**Fig(9)**

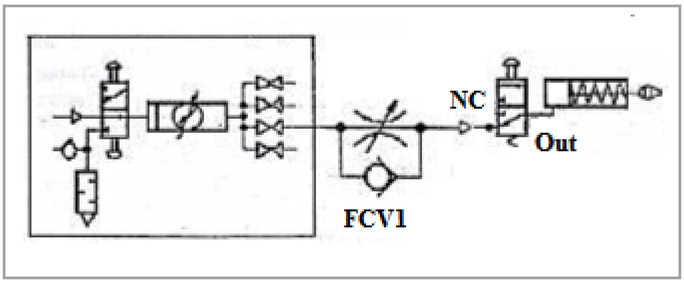
5. Open the shutoff valves and set the pressure regulator at 300 kPa .

6. Wait until the accumulator is filled with compressed air (30 sec approximately), then push the button on the directional control valve and observe the time taken for a full extension of the cylinder rood. Wait a few seconds and repeat.

**Question# 1**: What change do you observe in the time taken by the rod to fully extend? Explain.

**C) Speed contract of cylinder**

1. Connect the circuit shown Fig(10).
2. Close contract valve completely.
3. Set the pressure to100KPa and open the main shut off.
4. Open flow contract valve according to the Table(1).
5. Observe the speed of the extension and retraction of the piston. Is it increase, decrease or stay the same.




Fig(10)

| Flow control valve | Extension speed | Retraction speed |
| --- | --- | --- |
| 2 turn | | |
| 4 turn | | |
| 5 turn | | |

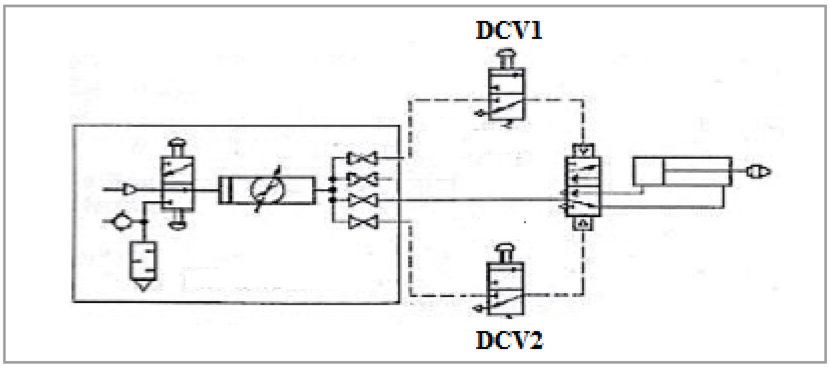
Table(1)

**Question#2**: Explain the relationship between the setting of the flow control and extension time of the rod.

**Question#3**: What do you observe about the retraction time of the rod? Explain.

## D) Indirect control using pilot operated valve

1. Connect the circuit shown in Fig(11).




Fig(11)

2. Open the main shutoff valve and the branch shutoff valves at the manifold and set the regulator at 100 KPa on the regulated pressure gauge.

3. Push down the button on the directional control valve DCV2 to set the spool in operated valve as illustrated in Fig(13).

**Question# 4**: Explain what happen to the piston?

4. Actuate the cylinder using the directional control valves DCV1and DCV2.

**Question#5**: Do the valves DCV1and DCV2 control the extension and retraction of the cylinder piston rod? Explain why and how.

5. Push down the button on the directional control valve DCV2 and maintain this position. With your other hand, push down the button on the directional control valve DCV1.

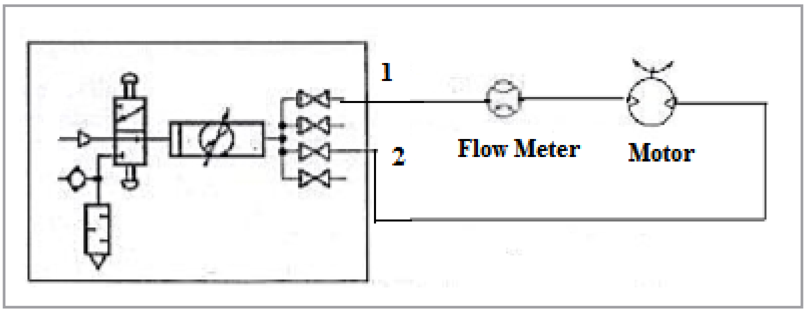
**Question#6**: Explain what happen to the piston?

6. Release the button on the directional control valveDCV2 then push down the button on the directional control valve DCV1and maintains this position. With your other hand, push down the button on the directional control valve DCV2.

**Question#7**: What happens?

## E) Pneumatic Motor Performance

1. connect circuit shown in Fig(12).
2. Open the branch shutoff valve number 1 and keep number 2 closed.
3. Use a tachometer to measure the rotational speed of motor
4. Complete the following Table(2).



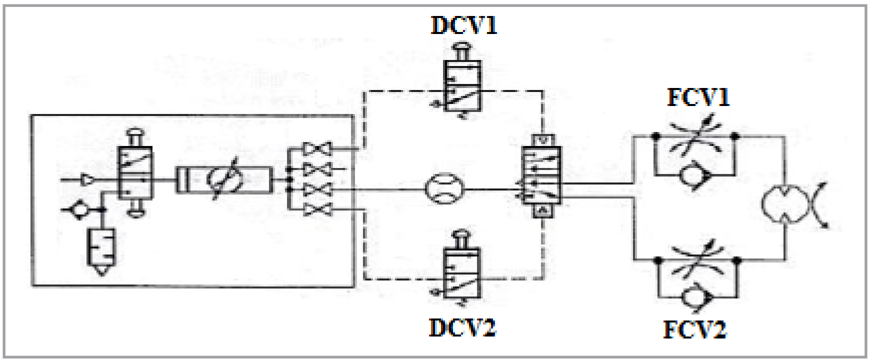

**Fig(12)**

| Pressure | Speed | Flow rate |
|---|---|---|
| 30psi | | |
| 35 psi | | |
| 40 psi | | |
| 45 psi | | |

**Table(2)**

## F) Directional and speed control of pneumatic Motor

1. Construct the circuit as shown in Fig(13).




**Fig(13)**

2. Open the flow control valves FCVl and FCV2, by turning the control knobs fully counter clockwise.

3. Open the shutoff valves and set the pressure regulator at 400 kPa .

4. Use the required directional control valve to set the motor rotation in the counter clockwise direction.

5. Adjust the flow control valve FCV1 to obtain a rotational speed as in the Table(3).

6. Push down the button on the directional control valve DCV2 to set the motor rotation in the clockwise direction.

7. Adjust the flow control valve FCV2 to obtain a rotational speed as in the Table(3).

| Flow rate | Speed(clockwise) | Speed(counter clockwise) |
|---|---|---|
| 30 | | |
| 35 | | |
| 40 | | |
| 45 | | |

**Table(3)**

**Question#8**: Draw relationship between flow rate and speed.

**Question#9**: From the values indicated in Table(3) what can you conclude about the operation of the circuit?

**REVIEW QUESTIONS**

1) The fluid power devices that convert the energy of a pressurized fluid into mechanical energy to do work are called

a. activators b .actuators c. accumulators d. converters.

2) Which gas is commonly used in pneumatics?

a. Oxygen b. Air c. Hydrogen d. Nitrogen.

3) Which two properties of compressed air make possible smooth acceleration and reversal of direction of mechanical motions?

a. Easy to store and very fast working medium. B. Elastic and very fast working medium

c. Compressible and elastic D. Efficient and compressible

4) Which of the following is not considered as an advantage of compressed air

a. Offers little risk of explosion B. No return line necessary.

c. Humidity may not be present. D. Enables high working speed to be obtained.

5) Mechanical energy is converted into fluid power when air is

a. compressed b. exhausted c. absent d. extended.

6) Which component is used to measure the pressure in a pneumatic circuit?

A. Lubricator B. Pressure gauge C. Flow control valve D. Regulator.

7) Relief valves are used to

A. limit the minimum pressure in a system B. to control the flow rate in a system

C. limit the maximum pressure in a system. D. to control the pressure in a system.

8) Which component is used to set the pressure in a pneumatic circuit?

A. Lubricator. B. Pressure gauge.

C. Flow control valve. D. Pressure regulator.

9) Accumulators are used to

A. provides a short term supply of compressed air. B. compressed air before entering the circuit.

C. Compress air to a particular value. D. maintain a constant pressure in a circuit.

10) Which of the following components is not a part of the conditioning unit?

A. Shutoff valve. B. Pressure gauge.

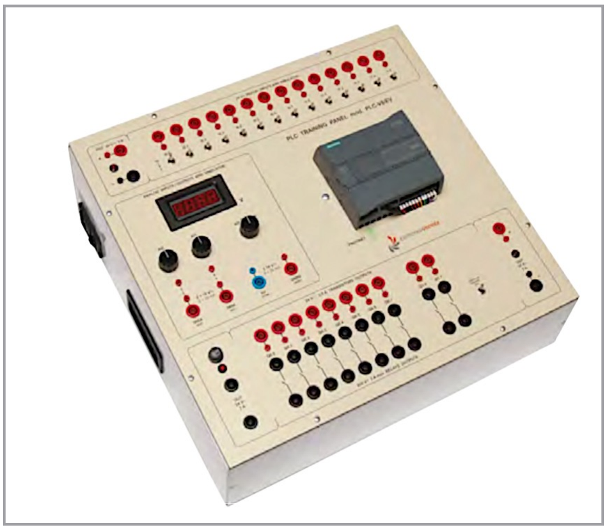
C. Flow control valve. D. Pressure regulators

# Electrical Engineering Department
# Control Lab
# Experiment #3
# PLC

**<u>Introduction</u>**

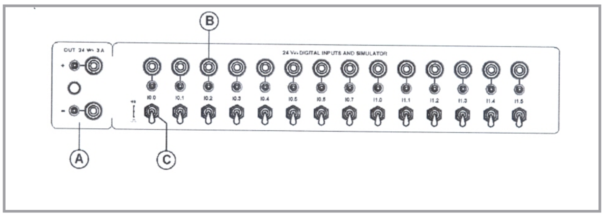
PLCs (Programmable Logic Controllers) these are microprocessor devices employed to solve industrial automation problems.
PLC consist of CPU, Inputs, Output memory and power supply.

In this lab we will use PLC model Siemens family S7-1200 which has 14 inputs and 10 outputs as shown in Fig(1).



**Fig(1)**

Fig(2) shows the digital inputs and simulator section.




**Fig(2)**

A) Terminals to power the PLC input devices.
B) Terminals for the connection of the PLC input devices.
C) Switches of the digital input simulator. The switch gives the *permanent* logic state 1 if shifted upward and the *pulse* logic state 1 if pressed downward (it operates as NO pushbutton).

**Creating a new program and opening an already present program**

To write a new program, we can start from the project ***TEST_1***, we save the new program with a different name, e.g. ***TEST_2***. So for all the future programs, we will use the project ***TEST_1*** as base.

1. From the desktop start up the software TIA PORTAL V13.
2. To create a new program:
    - From the displayed list, select the entry ***TEST_1***.
    - Push the pushbutton ***Open***.
3. In the displayed window, select ***Write PLC program***.
4. Double click on the icon ***MAIN***.

Open the block MAIN, a programming page is opened which by default is in language LADDER.

- The programming area is divided into Segments, each corresponding to a line of program.

To insert the programming elements, point out the line of the Segment and slip over the selected elements.

Each element of the program is identified with its code:

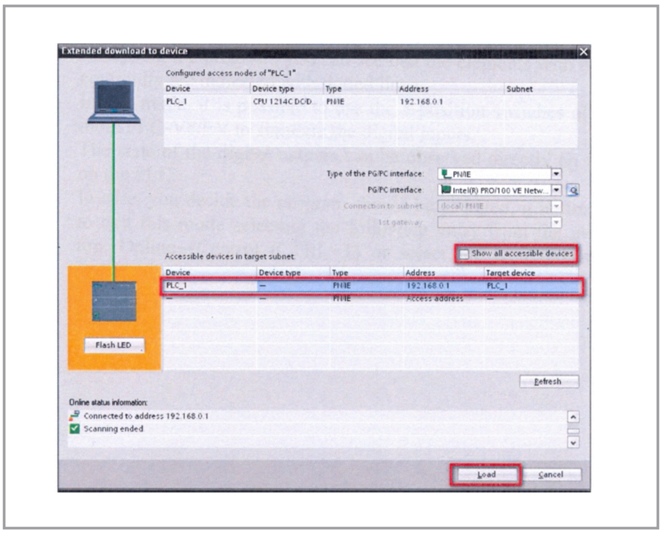
Input (Contacts) ➔ I*0.0 to* I*0.7* and I*1.0 to* I*1.5*
Output ➔ *Q0.0 to Q0.7* and *Q1.0 , Q1.1*

5. Before saving the program, it is necessary to ***compile*** it by selecting the compile icon.

6. Then saving by selecting the entry: Project ➔Save as on the menu on the top.
   write the name of the project and push the pushbutton Save.

**Downloading a program from PC to PLC**

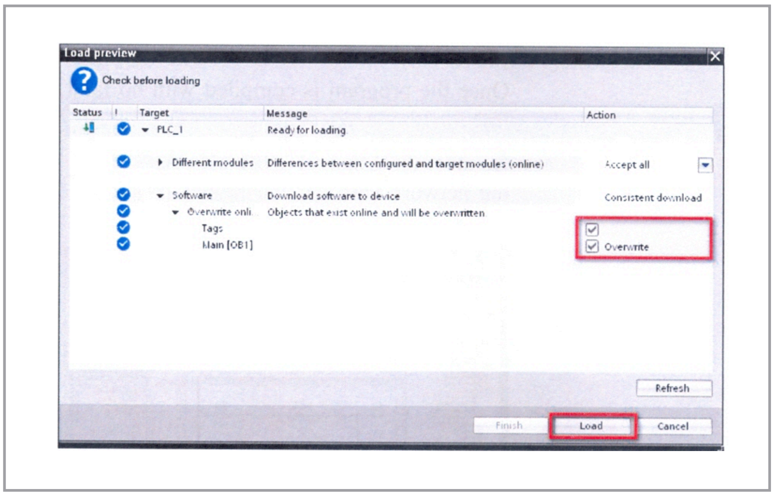
1. Click over the area of a Segment of the program using the mouse arrow.
2. Click over the *Download to* device icon from the top menu.



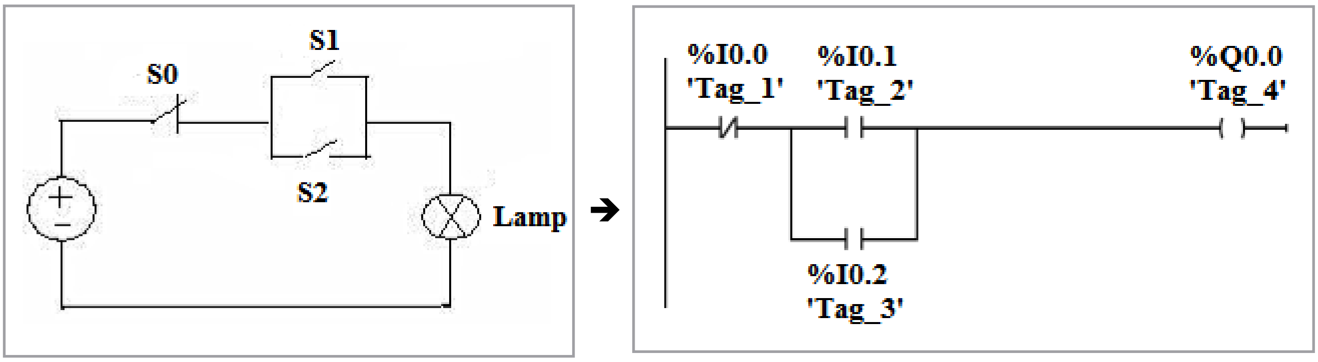

In the fields:

- Type of the PG/PC interface: select ***PN/IE.***
- Select ***start search*** and wait for scanning operation to finish.
- Choose the entry ***Show all accessible devices***.
- Point out the line reporting CPU 1214DC/DC/DC
- Push the pushbutton ***Load***.

In the new screen, press the pushbutton ***Load.***



Simulate the circuit shown in Fig(3) using LADDER in PLC:




**Fig(3)**

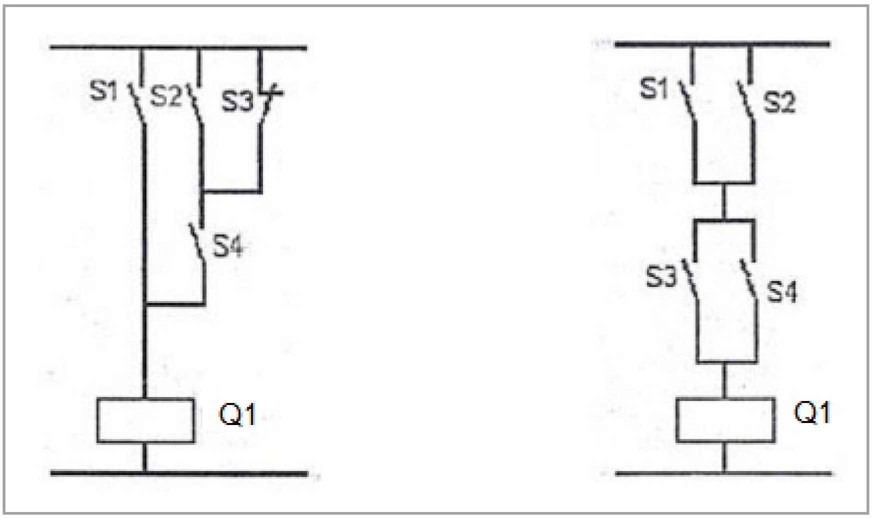
**<u>Objectives:</u>**

1. To become familiar with the structure of PLC.
2. To become familiar with simulation using PLC.
3. To use the set-rest operation on PLC.

## Experimental Procedure

### A) Part one

1. For the two circuits diagram shown in Fig(4).Construct the ladder diagram on PLC.
2. Test your program.

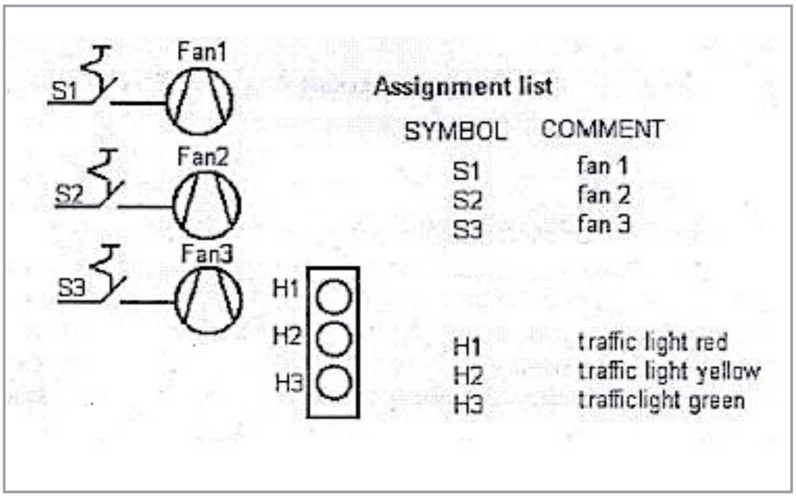



**Fig(4)**

### Exerscise#1:

Functional description and problem definition in an underground car park three fans for ventilation are installed that are switched on by means of the control switches S1-S3. If *all three fans* are operation sufficient ventilation is provided for thus the traffic Light shall flash *green*. If *only two fans* are in operation the traffic light shall flash *yellow*, *If less than two fans* are in operation the ventilation in the garage is not sufficient any more thus the traffic light shall flash *red*.

Process schematic ➔




**From the Exercise#1:**

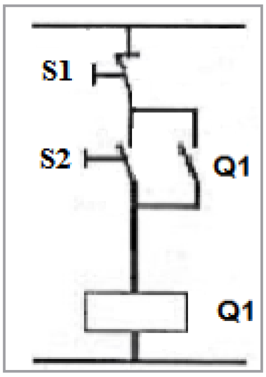
1. Draw truth table
2. Write logic equations described the system.
3. Construct ladder diagram on PLC.

**Exercise#2:**

Construct ladder diagram on PLC program to light 5 lamps from two switches, when you light from switch 1 you can turn off either from switch 1 or switch 2 and when light from switch 2 you can turn off either from switch1 or from switch2.

**B) Part two (Latch)**

1. Construct Ladder diagram on PLC for control circuit below.
2. Test your program.

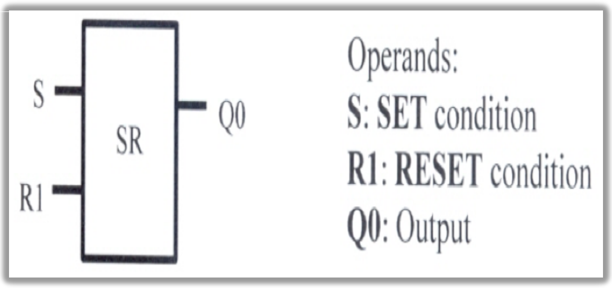



Control circuit

**Exercise#3:**

Construct ladder diagram on PLC program to light three lamps sequentially lamp2 will not switch on if lamp1 is not on, lamp3 will not switch on if lamp2 is not on.(Use three inputs and three outputs).

**C) Part three: Set-Rest Operation (FLIP –FLOP with priority RESET)**

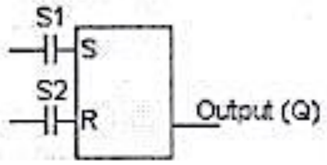



*Description:*

The block ***SR*** function is to make the output take the high (ON) or low (OFF) logic state according to the value present across the inputs. In the starting state, the output is OFF. The output takes the high logic state when the input ***SET (S)*** is ON and low when the input ***RESET (R1)*** is ON. In case the input ***SET (S)*** and ***RESET (R)*** should simultaneously be ON, the ***RESET*** input has priority, so the output Q0 is OFF.

The truth table for Set-Rest operation shown in Fig(5).

| S | R | Q-1 | |
|---|---|---|---|
| 0 | 0 | Qn-1 | (Previous case) |
| 0 | 1 | 0 | |
| 1 | 0 | 1 | |
| 1 | 1 | 0 | |




**Fig(5)**

**<u>Exercise#4</u>**

Construct SR Flip-Flop on PLC and test its operation.

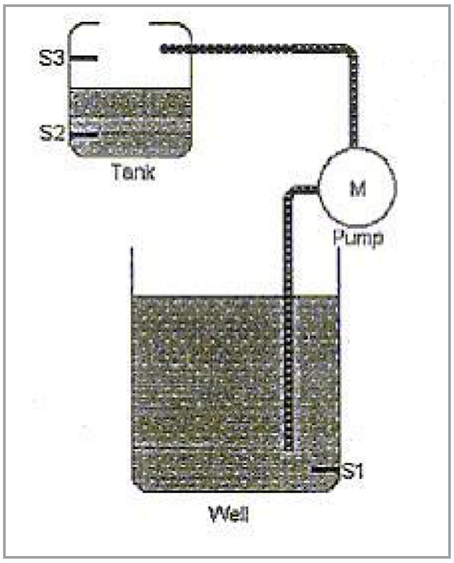
**<u>Exercise#5</u>**

**Filling Tank**

A pump used to fill water in a tank from a well, the well has one sensor the bottom, if the water in the well bellows it the pump will not run. The tank has two sensors, when the water below the bottom sensor the pump will start until reaches the above sensor then the pump will stop.

Fig(6) simulates the system well and tank.

1. Construct the ladder diagram on PLC.
2. Test your program.




**Fig(6)**

# Electrical Engineering Department
# Control Lab
# Experiment #4
# Introduction to control system

**Objectives**

1. To study the unit step response of first second order system.
2. To study the effect of plant parameter in closed loop and open loop system.

**Introduction**

**1) First order system**

A first order system has a transfer function:

$$G_s = K_s/(T_s + 1)$$

So the output of such system is:

$$C_s = K_s R_s/(T_s + 1)$$

If R(s) is unit step input then:

$$C_t = K(1 - e^{-t/T})$$

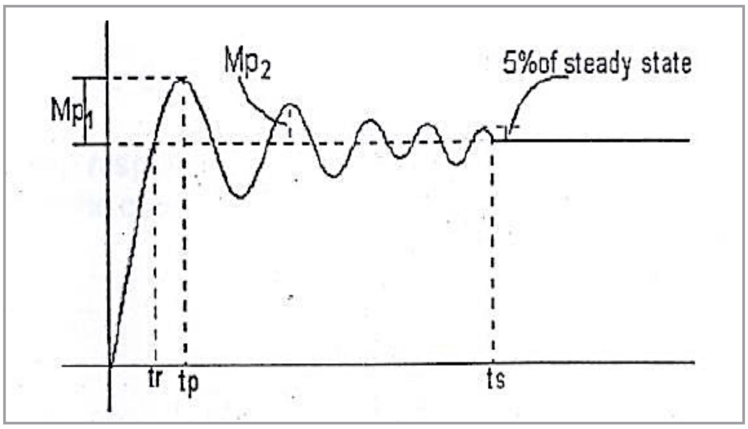
**2) Second order system**

A second order system has transfer function the behaviour of the output depends on two parameters $(\zeta, w_n)$.

If R(s) is unit input, the output will be one of the following case:

1- If $\zeta = 0$ ➔ The system oscillating.
2- If $0 < \zeta < 1$➔ The system under damping.
3- If $\zeta = 1$ ➔ The system critical damping.
4- If $\zeta > 1$ ➔ The system over damping.

For under damping system we must take care of the following parameters:

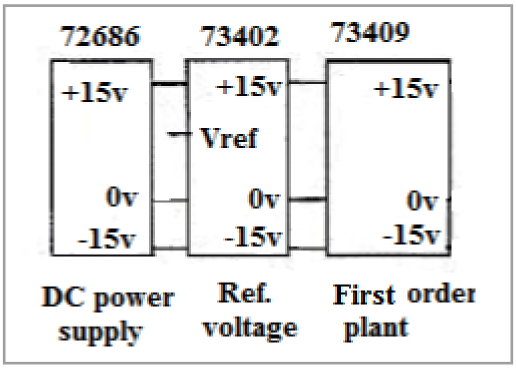



$M_p$: peak over shoot. $t_r$ : rising time.
$t_p$: peak time $t_s$ : settling time. Decay Ratio= $M_{p2}/M_{p1}$

## Experimental procedure

### A) Unit step response of first order planet

1. Connect the circuit shown in Fig (1).




**Fig(1)**

2. Adjust the reference variable generator to give ***(1Volt)***, and on the oscilloscope: Choose suitable values of time/div and amplitude/div.
3. Tabulate your results in Table(1).

| | $K_s = 1$ | | | $K_s = 1.5$ | | |
|---|---|---|---|---|---|---|
| $T$ | Steady state voltage $(V)$ | $t_s$ | Draw output to scale | Steady state voltage$(V)$ | $t_s$ | Draw output to scale |
| 1×0.1 | | | | | | |
| 1×1.0 | | | | | | |
| 1×7 | | | | | | |

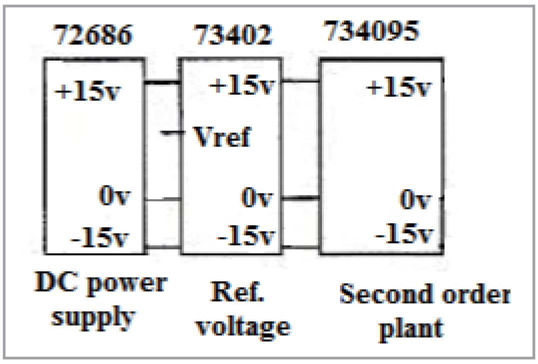
**Table(1)**

**Question#1**

a) Dose the settling time change as $T$ change, how?
b) Dose the change of $K_s$ effect to the settling time of plant, how?

**B) Unit step response of second order plant**

1. Connect the circuit as shown in Fig(2).




**Fig(2)**

2. Adjust the damping coefficient of the second order system ($\zeta$) as shown in table below and tabulate the results in Table(2).

| $\zeta$ | $T$ | $M_p(v)$ | $t_r$(sec) | $t_s$(sec) | Draw output |
|---|---|---|---|---|---|
| 1.1 | 1 | | | | |
| 1 | 1 | | | | |
| 0.7 | 1 | | | | |
| 0.5 | 1 | | | | |
| 0.4 | 1 | | | | |
| 0.2 | 1 | | | | |

**Table(2)**

3. Adjust the time constant ($T$) of the second order system as shown in table below and tabulate the results in Table(3).

| $\zeta$ | $T$ | $M_p(v)$ | $t_r$(sec) | $t_s$(sec) | Draw output |
|---|---|---|---|---|---|
| 0.5 | 0.03 | | | | |
| 0.5 | 0.1 | | | | |
| 0.5 | 0.3 | | | | |
| 0.5 | 1 | | | | |
| 0.5 | 3 | | | | |

**Table(3)**

**Question#2**

How does the change in damping coefficient ($\zeta$) effect on the output of the system? How does the change in time constant ($T$) effect on the output of the system?

**Question#3**

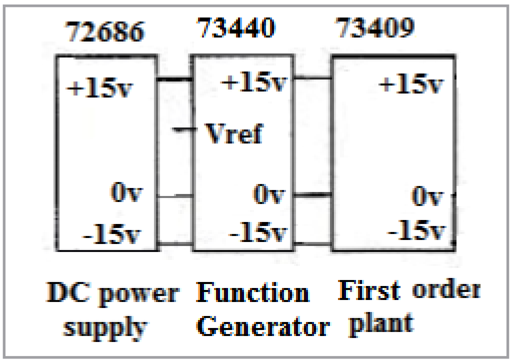
Calculate decay ratio for the case $\zeta = 0.2 \quad , T = 1$.

**Question#4**

What is the relation between $T$ of the second order system and $W_n$.

**C) Unit impulse response for First order planet**

1. Connect the circuit shown in Fig(3).

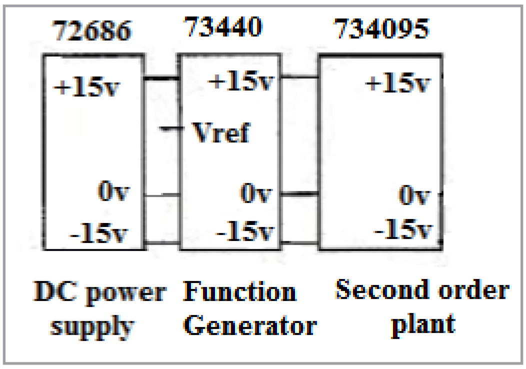



Fig(3)

2. On the function generator unit adjust it to the **impulse function**, rotate the frequency knob to minimum and voltage knob to the middle.
3. Connect the output of function generator from impulse exit to the input of first order system.
4. On the oscilloscope choose suitable values of time/div and amplitude/div.
5. Select $\boldsymbol{K_s = 1}$ and $\boldsymbol{T = 1 \times 0.1}$.
6. Switch the power supply on, draw to scale the output of first order plant from oscilloscope .

**D) Unit impulse response for second order plant**

1. Connect the circuit shown in Fig(4).




Fig(4)

2. On the function generator unit adjust it to the **impulse function**, rotate the frequency knob to minimum and voltage knob to the middle.
3. Connect the output of function generator from impulse exit to the input of second order system.
4. On the oscilloscope choose suitable values of time/div and amplitude/div.
5. Adjust the damping coefficient of second order to and $\boldsymbol{\zeta = 0,5}$and $\boldsymbol{T = 0.2\times1.}$
6. Switch the power supply on. Draw to scale the output of second order plant from oscilloscope.

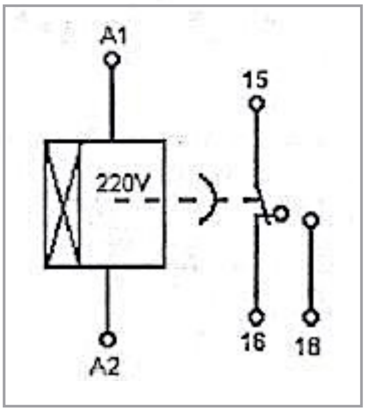
**Electrical Engineering Department**
**Control Lab**
**Experiment #5**
**Motor Control**

## Objectives

1. To investigate delay-on auxiliary contactor and time relay.
2. To investigate motor reversing control circuits.

## Introduction to timers

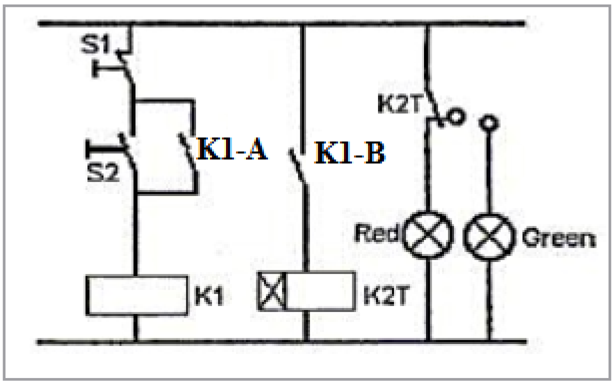
The time can assign in the timer in order the system to work or shut down after a certain time. When a voltage (220volt) applied to points $A_1 and\ A_2$, the time count in the timer will start, if our plant connected throw points(15 and 16), then it will run for a certain time then stop, but if our plant is connected through point (15 and18), it will run after a certain time and continue to run .Fig(1) shows the timer symbol.



**Fig(1)**

## Experimental Procedure

1. Connect the circuit as shown in Fig(2).



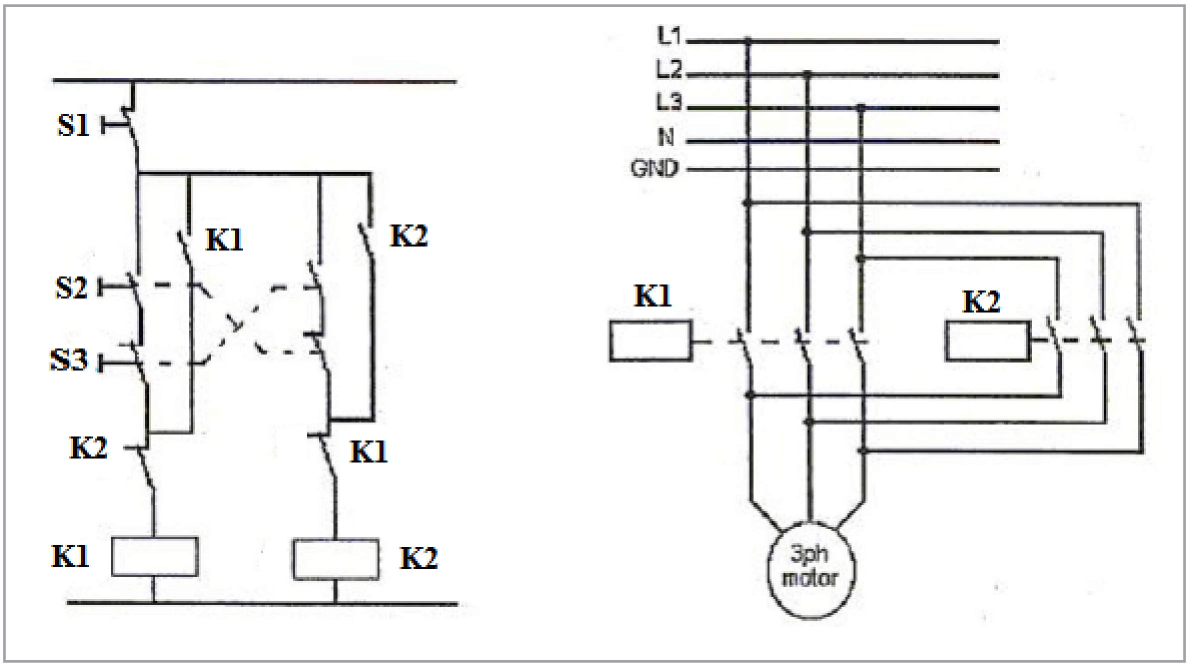
**Fig(2)**

2. Set the timer time to 5s.

## Reversing control circuit

In reversing control circuit, it is necessary to be sure that the circuit will not work in the reverse direction without ***stopping the motor at first***.

1. Construct the circuit shown in Fig(3).




**Fig(3)**

2. Explain what happen if we push both S1 and S2 at the same time?
3. Use the required changes for the same circuit in Fig(3) ***to make the motor reverse its direction after 5sec.***

## Exercise

Construct a wiring circuit to light three Lamps for 6sec from three positions, after 6sec the lamps will be off. If we want to light again we can push any of switches.

**Equipment required:**

- Three bush buttons.
- One timer.
- One contactor.
- Three lamps.

1) Draw the circuit diagram.
2) Construct the circuit diagram.

# Electrical Engineering Department
# Control Lab
# Experiment #6
# Basic Electrically-Controlled Pneumatic Circuits

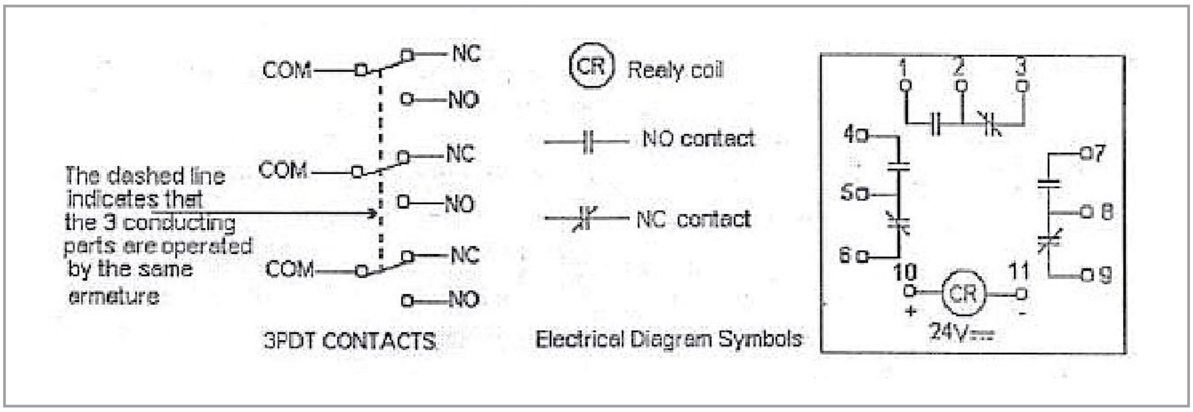
**Objectives**

1. To introduce cylinder reciprocation.
2. To describe the function and operation of magnetic proximity switches.
3. To introduce indirect control using solenoid-operated directional valves.

**Introduction**

**A) Electromechanical Control Relays**

Electromechanical control relays are used to perform complex logic functions as shown in Fig(1), they consist of **a relay coil, a magnetic core, an armature and one or more sets of normally-open (NO) and normally closed (NC) contacts** .When current flows through the relay coil, the magnetic core and armature attract each other causing the armature to move towards the core. This switches the relay contacts to the activated state. The NO contacts go closed while NC contacts go open. When the current is removed from the relay coil the armature is moved back to its original position by a spring which returns the relay contacts to their normal state.

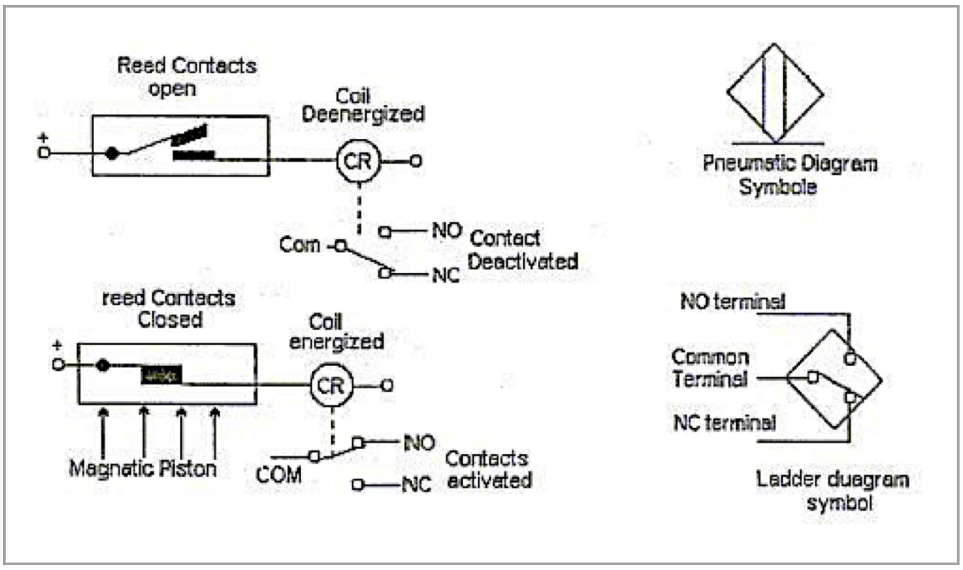



**Fig(1)**

The relay you have consists of a relay coil and three sets NO and NC contacts. The relay is the triple-pole, double-throw (3PDT) type, because it simultaneously switches three conducting parts back and forth between two positions.

**B) Magnetic Proximity Switches**

In the circuit of Fig(2) automatic reversal of the cylinder is achieved by using the electrical signal provided by a magnetic proximity switch when the cylinder rod becomes extended. Magnetic proximity switches are widely used in industrial pneumatic systems **to sense the position of a cylinder piston**. They can be mounted anywhere, within the piston travel range. The magnetic proximity switches supplied with your trainer are of the Reed type. As Fig(2) shows each switch consists of an internal relay coil controlling a set of NO and NC contacts of the single-pole, double - throw (SPDT) type, and two mechanical reeds (contact point). The (+) and (-) terminals are to be connected to the DC power supply.



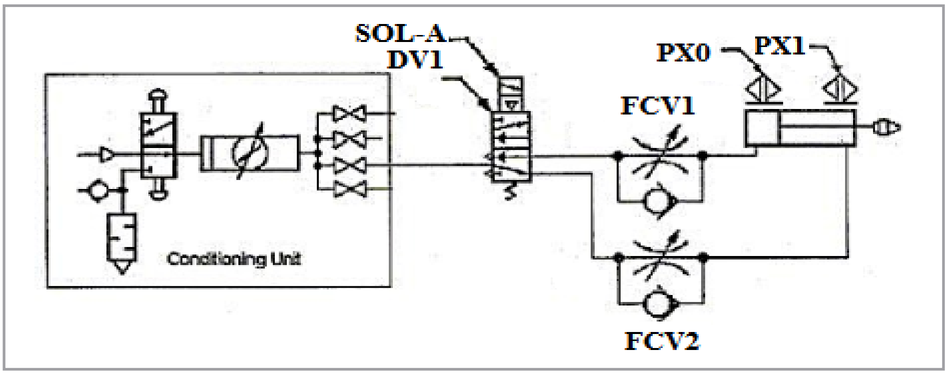

**Fig(2)**

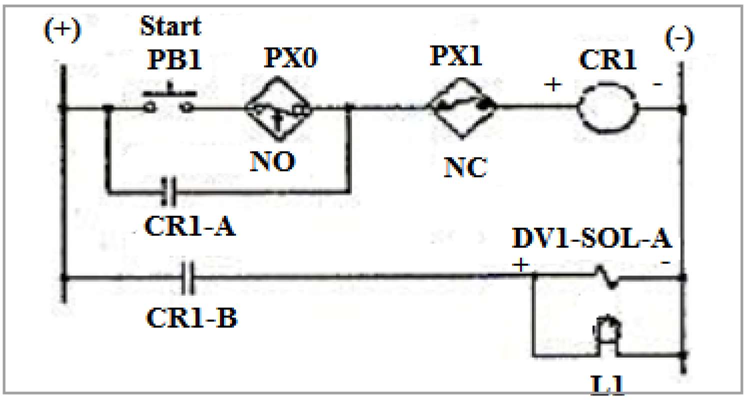
When the magnetic piston located in the cylinder comes within proximity of the switch, the magnetic field pulls the reed switch contacts together allowing the current to flow from the (+) terminal to energize the relay coil. This causes the switch SPDT contacts to activate.
The NO contact goes closed while the NC contact goes open. When the magnetic piston moves away from the switch the reed switch contacts separate de energizing the relay coil and the switch contacts return to their normal deactivated state.

## Experimental Procedure

### A)One-cycle reciprocation circuit

1. Connect the one-cycle reciprocation circuit shown in Fig(3).




**Fig(3)**

**1)Testing the electrical circuit**

1. Turn on the DC power supply. **Don't** open the shutoff valves on the conditioning unit at this time.
2. Momentarily depress the **START** push button. If the electric circuit is working pilot lamp LI should turn on.

**Question#1**
Is pilot lamp of solenoid SOL-A turned on to indicate that the solenoid is energized?

**Question#2**
With your hand, pull the cylinder rod until it is fully extended. If your circuit is operational, the pilot lamp LI should turn off. Explain why?

**2) Testing the one-cycle reciprocation**

1. Open the shut off valve and the branch shut off valve at the manifold and set the pressure regulator a 400 KPa on the regulated pressure gauge.
2. Start the cylinder cycle by momentarily depressing the START push button PB1.

**Question#3**
What the cylinder rod does?

3. Start another cycle by momentarily depressing PB1.

**Question#4**
Is retraction automatic when the cylinder rod becomes fully extended? Explain why by referring to the ladder diagram in Fig(3).

4. Start another cycle by momentarily depressing PB 1.

**Question#5**
Does the cylinder continue to extend when you release PB1? Explain why by referring to the ladder diagram in Fig(3).

5. Loosen the set screw on the magnetic switch PX1 until the clamp is loose enough to slip over the cylinder tie rod. Position the switch approximately at the middle of the cylinder then tighten the set screw.
6. Start the cylinder cycle by momentarily depressing PB1 while observing the extension of the rod.

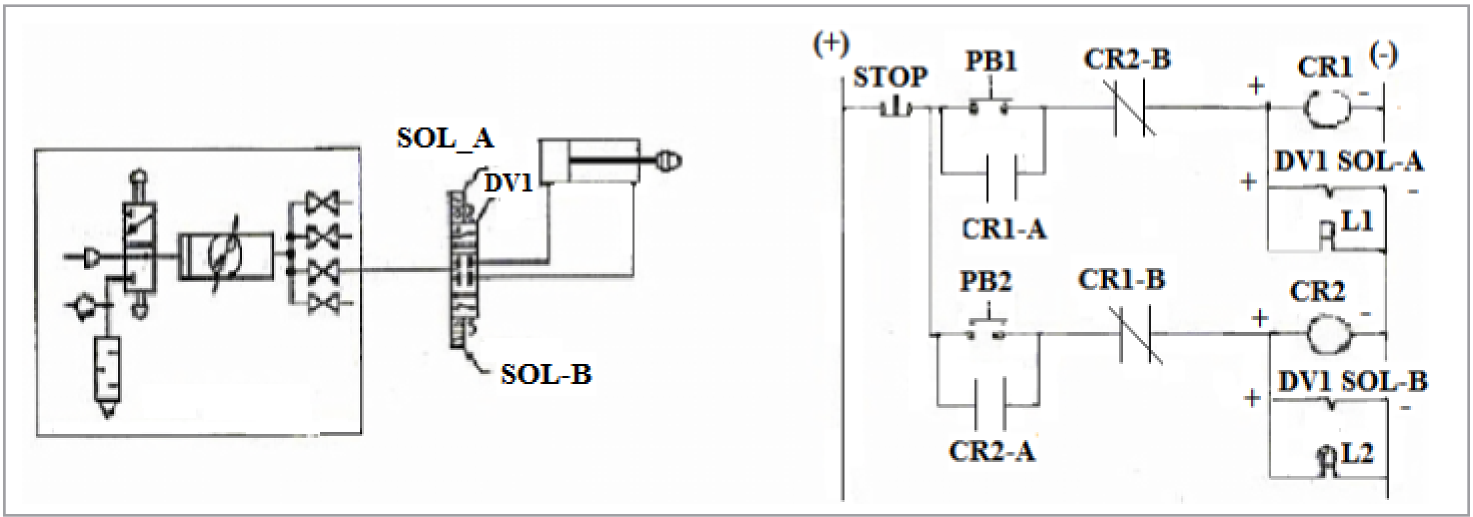
**Question#6**
From your observations, what can you conclude about the position of the magnetic switch?

**Question#7**
What would happen to circuit operation if relay contact (CR1-A) were removed? Would you still be able to fully extend the cylinder rod? Explain.

**Question#8**
What is meant by one-cycle recuperation?

**B) Interlock Circuit**

1. Connect the interlock circuit shown in Fig(4).




**Fig(4)**

2. Turn on the DC power supply.
3. On the conditioning unit open the shutoff valves and set the pressure regulator at 200kPa.

**Question#10**
Momentarily depress push button PB1. If the electric circuit is working pilot lamp L1 should turn on. Does pilot lamp L1 continue to light when you release PB1? Explain why.

**Question#11**
Momentarily depress push button PB2, Does the pilot lamp L2 turn on?

**Question#12**
Depress the STOP push button, and then depress momentarily pushbutton PB2.Does pilot lamp L2 turn on?

**Question#13**
Depress simultaneously push buttons PB1 and PB2. Do pilot lamps L1 and L2 turn on?

**Question#14**
Does the operation of the interlock circuit confirm that circuit (prevents the solenoids from being energized simultaneously)?

**Electrical Engineering Department**
**Control Lab**
**Experiment #7**
**Timers and counters on PLC**

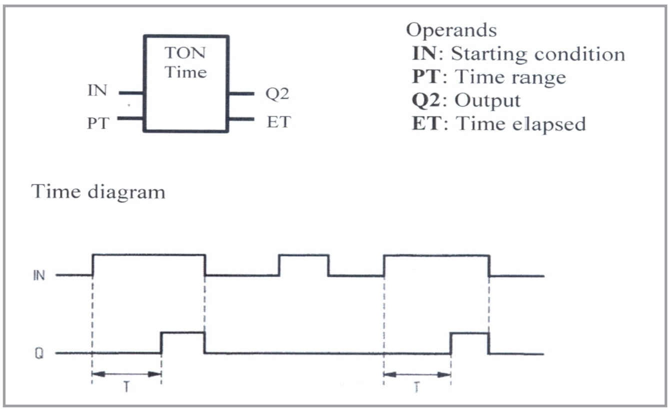
## Objectives

1. To understand the on delay timer and off delay timer operation on PLC.
2. To understand the counter up and counter down operation on PLC.

## Experimental Procedure

### A) Part one: Timer operations

1. ON Delay Timer (TON Timer)

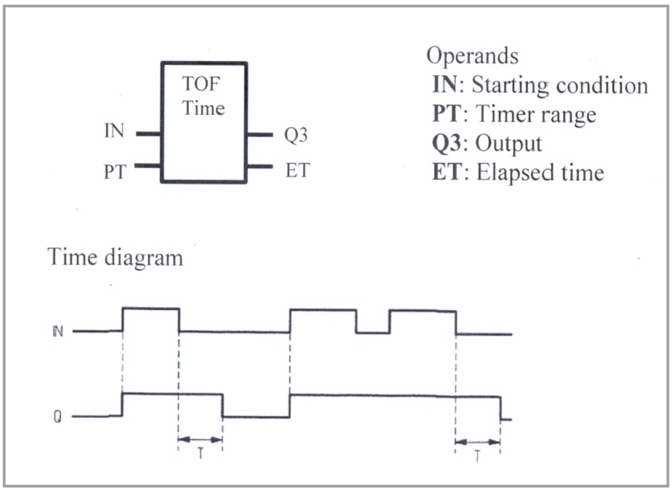



*Description:*
The Timer range is specified across the input ***PT*** after which starting from the rising edge of the signal ***IN***, the output ***Q2*** must take the high logic state.

### Exercise#1

Construct TON Timer to turn on after 8s on PLC program.

2. <u>OFF Delay Timer (TOF Timer)</u>




*Description:*
The elapsed timer range is specified across the input ***PT*** after which starting from the falling edge of the signal ***IN***, the output ***Q3*** has to take the high logic state.

**Exercise#2**
Construct TOF Timer to turn off after 7s on PLC program.

**Exercise#3**
**Stair case problem**

Lighting stair from 5 positions using pushbuttons, it is required to light 4 lamps from 5 positions for 5 sec then the lamps shut off automatically, pushing any switch will light the lamps for another 5sec.

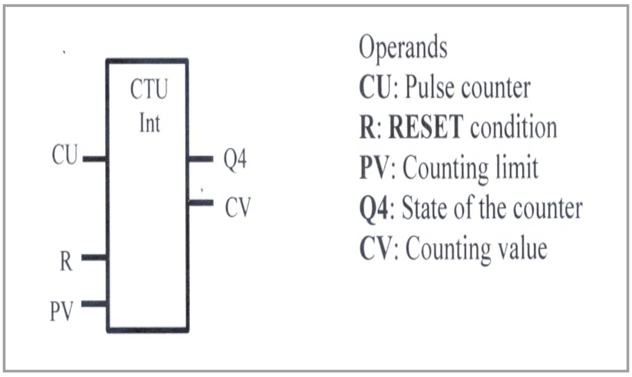
1. Construct ladder diagram.
2. Test your program.

**Exercise#4**
**Reversing motor direction**
Motor can rotate at clockwise direction when switch number one is pushed on when switch number two is pushed on the motor will not rotate counter clock wise before 6 sec.

1. Construct ladder diagram.
2. Test your program.

B) <u>**Part two: Counter operations**</u>

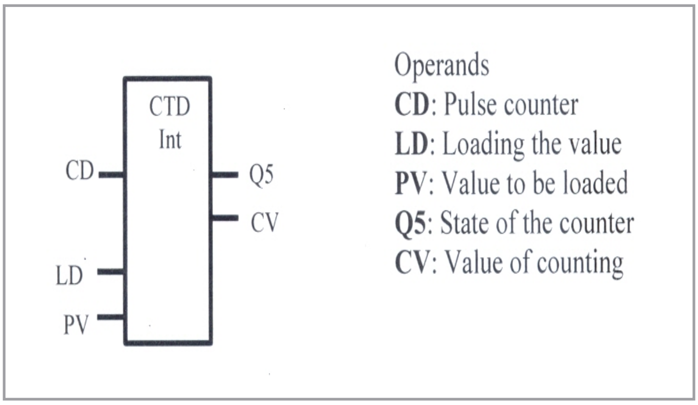
1. <u>CTU forward counter</u>




*Description:*
The block ***CTU*** carries out the forward counting according to the pulses reaching the input ***CU***. When it is initialized, via the input RESET, it takes the value (0) and then the value present in ***CV*** is incremented of (1) at each rising edge of the signal.
It is necessary to chose the upper limit value with ***PV***. The output ***Q4*** is ON when the counting is higher or equal to the value of ***PV***.

**Exercise#5**
Construct CTU counter operates after 4 pulses on PLC program.

2. <u>CTD backward counter</u>




*Description:*
The block ***CTD*** carries out the backward counting according to the pulses reaching the input ***CD***. When initialized, via the LOAD input, it takes the set ***PV*** value. After which at each rising edge of the signal the value in ***CD*** is decremented of (1).

The output ***Q5*** is ON only when the counting is lower or equal to zero.

**Exercise#6**
Construct CTD counter operates after 4 pulses on PLC program.

**Exercise #7**

In a certain system a lamp to be light when the counter reaches 2 and will be off when the count reaches 5.

Construct the ladder diagram for the system.

**Exercise #8**

In a certain industrial process is need to paint balls, the paint process will start after 5 balls arrived and it will last for 5 sec.

Construct the ladder diagram for the system.

**Electrical Engineering Department**
**Control Lab**
**Experiment #8**
# Open loop and closed loop system

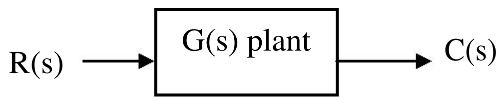
## Objectives

1. To understand the open loop and closed loop concept.
2. To study the effect of changing parameters of closed loop and open loop system.
3. Effect of disturbance on open and closed loop systems.

## Introduction:

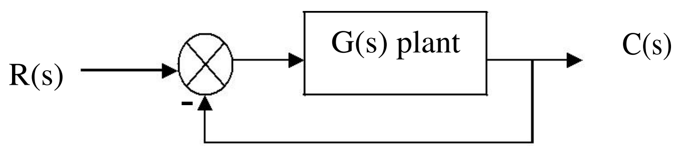
In the open loop system the output is directly connected to the input as shown in Fig(1).

$$C(s) = G(s)R(s)$$




**Fig(1)**

In closed loop system with unity feedback it can be represented as shown in Fig(2).




**Fig(2)**

The output is given by:

$$C(s) = \frac{G(s)}{1 + G(s)}$$

In this experiment we will use the first order and second order plant transfer function of 1st and 2nd order plant is given the following equations:

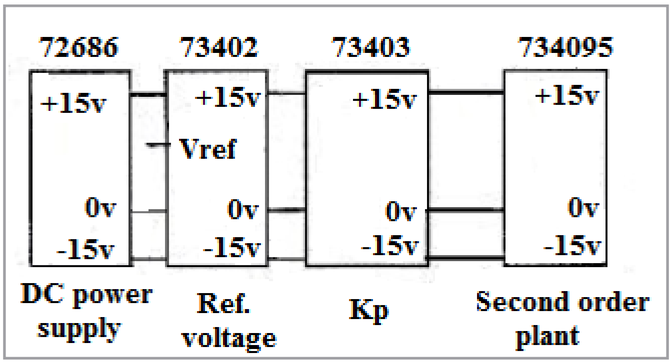
$$G(s) = \frac{KS}{1 + T_s}$$

$$G(s) = \frac{G(s)}{\tau^2 s^2 + 2d\tau s + 1}$$

**Experimental procedure**

**A) Effect of changing plant parameters on open loop system**

1. Connect the system shown in Fig(3).




**Fig(3)**

2. Set the reference variable voltage to ***(1volt)***. Adjust the parameter of 2nd order plant as follow:
**Note: Find Mp , tr and ts at each cases.**

a. $K_p$ change by 20%.

| $\zeta$ | $T$ | $K_p$ | Sketch output |
|---|---|---|---|
| * 0.5 | 2 | 5 | |
| 0.5 | 2 | 4 | |

**Table(1)**

b. Damping coefficient $\zeta$ change by 20%.

| $\zeta$ | $T$ | $K_p$ | Sketch output |
|---|---|---|---|
| * 0.5 | 2 | 5 | |
| 0.4 | 2 | 5 | |

**Table(2)**

c. Time constant $T$ change by 20%.

| $\zeta$ | $T$ | $K_p$ | Sketch output |
|---|---|---|---|
| * 0.5 | 2 | 5 | |
| 0.5 | 3 | 5 | |

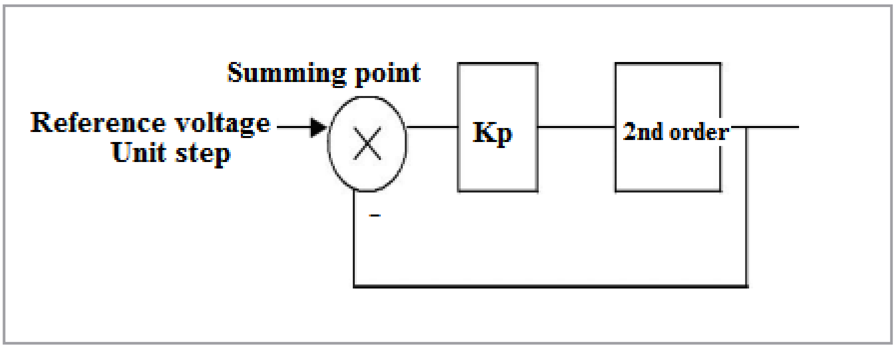
**Table(3)**

**Discuss**

1. The effect of changing $K_p$ on the output performance.
2. The effect of changing damping coefficient $\zeta$ on the output performance.
3. The effect of changing time constant T on the output performance.

**B) Effect of changing plant parameters closed loop system.**

1. Connect the system shown in Fig(4).




**Fig(4)**

2. Set the reference variable voltage to ***(1volt)***. Adjust the parameter of 2nd order plant as follow:

**Note: Find Mp , tr and ts at each cases.**

a. $K_p$ change by 20%.

| $\zeta$ | $T$ | $K_p$ | Sketch output |
|---|---|---|---|
| * 0.5 | 2 | 5 | |
| 0.5 | 2 | 4 | |

**Table(4)**

b. Damping coefficient $\zeta$ change by 20%.

| $\zeta$ | $T$ | $K_p$ | Sketch output |
|---|---|---|---|
| * 0.5 | 2 | 5 | |
| 0.4 | 2 | 5 | |

**Table(5)**

c. Time constant $T$ change by 20%.

| $\zeta$ | $T$ | $K_p$ | Sketch output |
|---|---|---|---|
| * 0.5 | 2 | 5 | |
| 0.5 | 3 | 5 | |

**Table(6)**

**Discuss**

1. The effect of changing $K_p$ on the output performance.
2. The effect of changing damping coefficient $\zeta$ on the output performance.
3. The effect of changing time constant T on the output performance.

**Question**

Compare between the results for closed loop system and open loop system.

# Electrical Engineering Department
# Control Lab
# Experiment #9
## A- Star-Delta Starter
## B- Speed Control of three Phase Asynchronous Motor

**Objectives**

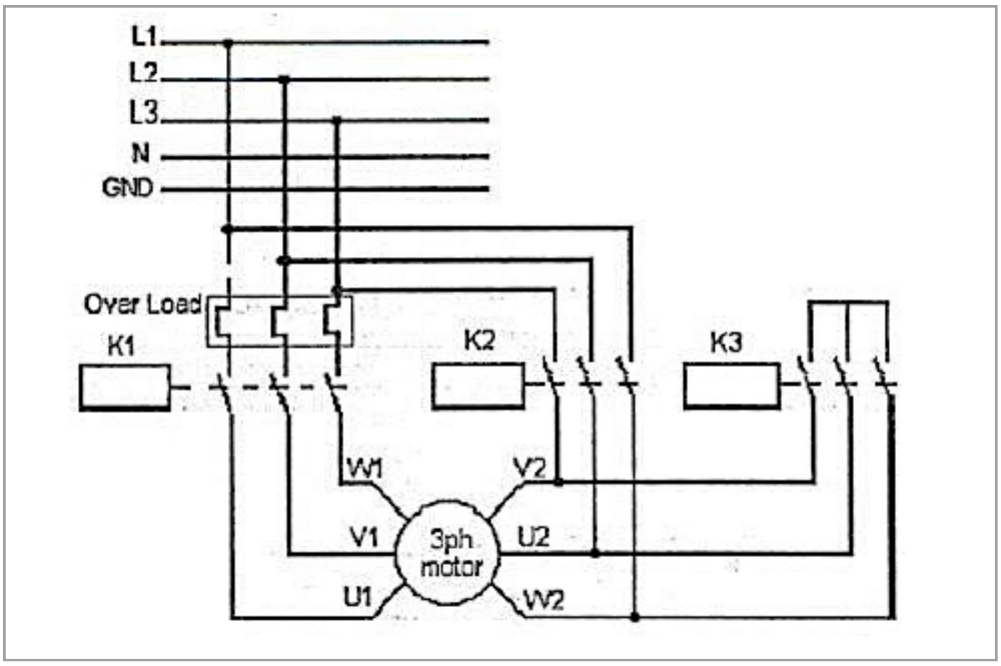
1. To investigate star -delta starter.
2. To control the speed of three phase Asynchronous Motor.

**A) Star-Delta circuit**

**Switching conditions for the main circuit:**

When the star contactor K3 and the main contactor K1 are switch on; the motor starts in star circuit. In the delta circuit; the motor runs when the delta contactor K2 and the main contactor K1 are activated. During switch over the star circuit must switch off first then delta circuit. Fig(1) show the power circuit for star delta connection

**Note:** ***K2 and K3 may never be activated simultaneously.***




**Fig(1): Power circuit for star delta connection.**

**Question#1**

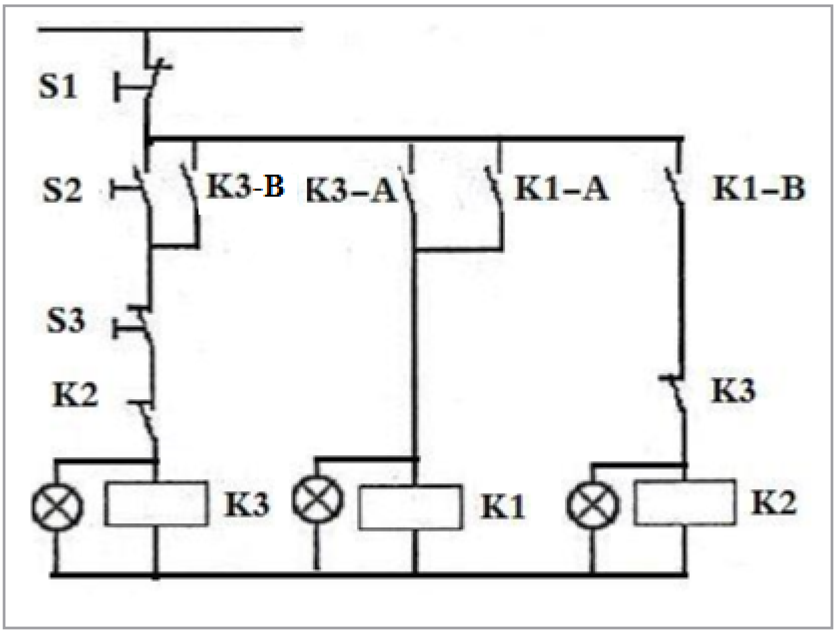
What would happen if K2 and K3 are activated simultaneously?

**Switching condition for the control circuit**

Basically all of the star delta circuits must be designed so that the star contactor always switches off first before the delta contactor can be switching over from star to delta. Otherwise short circuit occurs due to switching overlaps in the main circuit.

**Exercise#1**

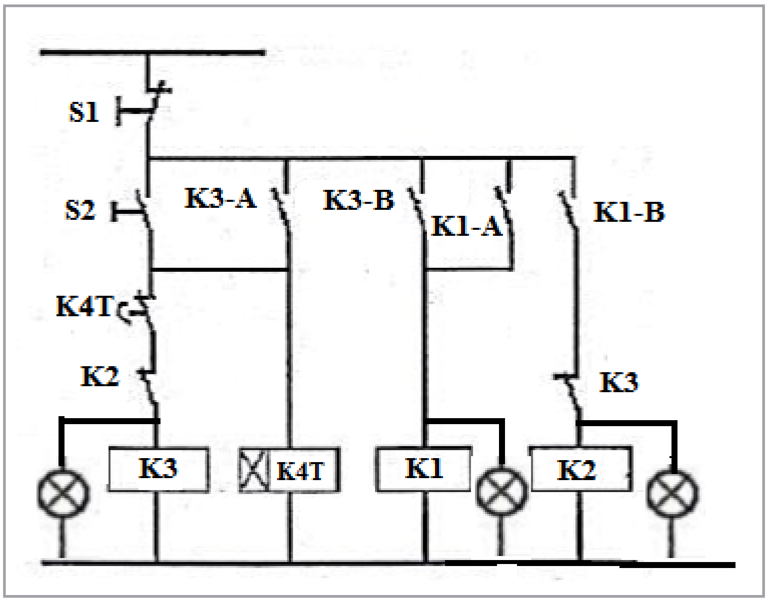
Develop a control for a Star-Delta circuit in which the switch over can be carried out manually via push button operation. Assemble the control develop in Fig(2) together with the main circuit Fig(1) and test the operation.




**Fig(2)**

**B) Star-Delta circuit with time relay.**

1. Develop a control circuit for star-delta starter in which after an 6 second time delay the switch over from star to delta follows automatically. A time relay for a short term operation is to be used for the automatic switch over
2. Assemble the control circuit Fig(3) with the main circuit according to the criteria above and put the circuit into operation.



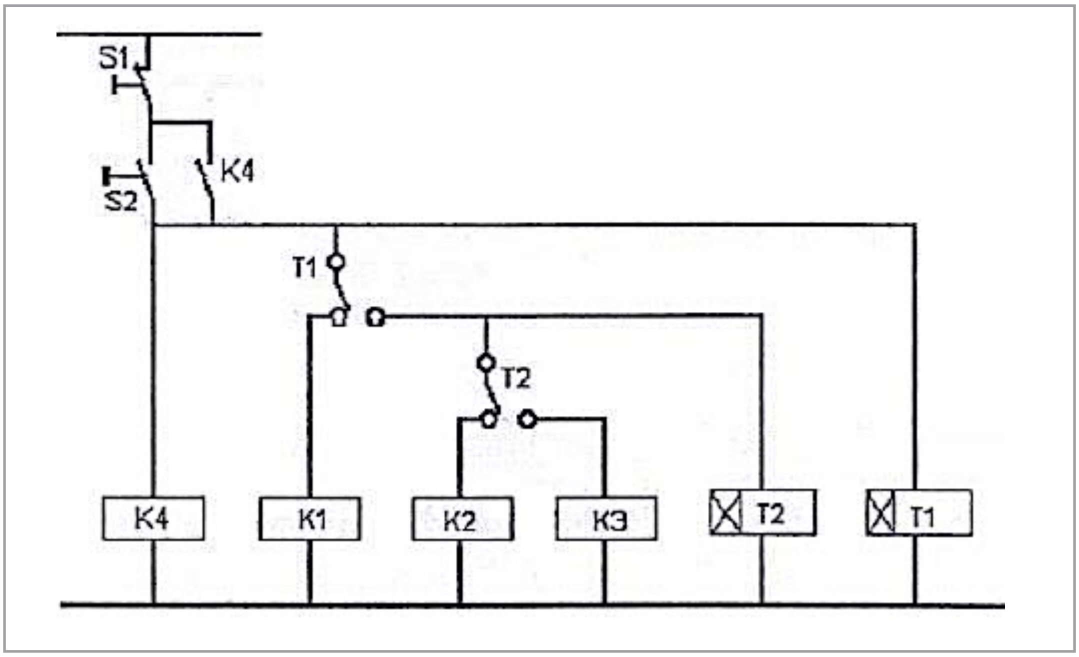

**Fig(3)**

**Exercise #2: Three- Speed Motor**

It is desired to run three phase motor, when starting switch to on position the lower speed start after 5 second the mid speed is operated after 9 second the highest speed is operated.

**Note**: ***Never two speeds operate at the same time.***

Fig(4) shows the control circuit.




**Fig(4)**

➔ Design the power circuit then build-up both power circuit and control circuit.

# Electrical Engineering Department
# Control Lab
# Experiment #10
# Timers and Counters in Pneumatics Circuits

## Part One: Timers

## Objective

1. To describe the operation of a time-delay relay.
2. To introduce time-delays.

## Introduction

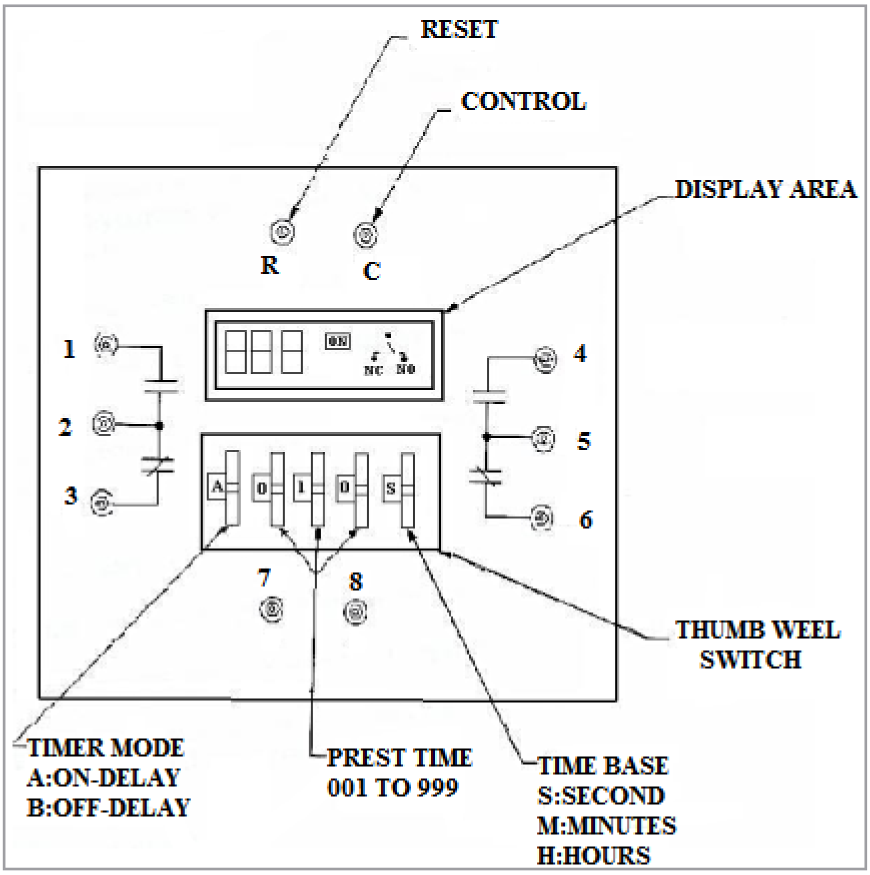
### Time-Delays

Time-delays are commonly used in machining operations to delay the start-up of a cylinder, start a series of cylinders one at a time, or hold a cylinder in a predetermined position for some period of time. For example, a metal drilling operation may require the drill bit to remain in the hole temporarily to clean up the cut after drilling through the metal. This function, called "cylinder dwell", is accomplished through the use of a time-delay valve or by a time -delay relay that prevents the drill cylinder from retracting immediately after reaching the end of the extension stroke.

Time-delay relays are also designed to create a delay between two operations of a work cycle. They basically consist of a solenoid coil, an internal timer, and one or more sets of NO and NC relay contacts. They can be designed for either ON-delay or OFF-delay operation.

In an ON-delay circuit, the relay is energized after a preset time period has elapsed. In an OFF-delay circuit, the relay energizes immediately, and de-energizes immediately when the preset time elapses.

The time-delay relay supplied with your trainer is shown in Fig(1). It can be programmed for either timing or counting function by configuring the thumbwheel switches on the unit.




**Fig(1) : Time-Delay Relay/Counter.**

To program the time-delay relay/counter for the timing function, three parameters must be configured: the "timer mode", the "preset time" and the "time base".

1. The ***"Timer Mode"*** switch selects between the following timer modes:

a. *ON-delay (switch set to A)*: In this mode, the internal timer starts when the CONTROL (C) input is switched to common (-). When the preset time has elapsed, both sets of relay contacts are activated. Momentarily switching the RESET (R) input to common deactivates both sets of relay contacts and resets the timer value.

b. *OFF-delay (switch set to B)*: In this mode, the internal timer starts and both sets of relay contacts are activated immediately when the CONTROL(C)input is switched to common (-). When the preset time has elapsed, both sets of relay contacts are deactivated. Momentarily switching the RESET (R) input to common deactivates both sets of relay contacts and resets the timer value.

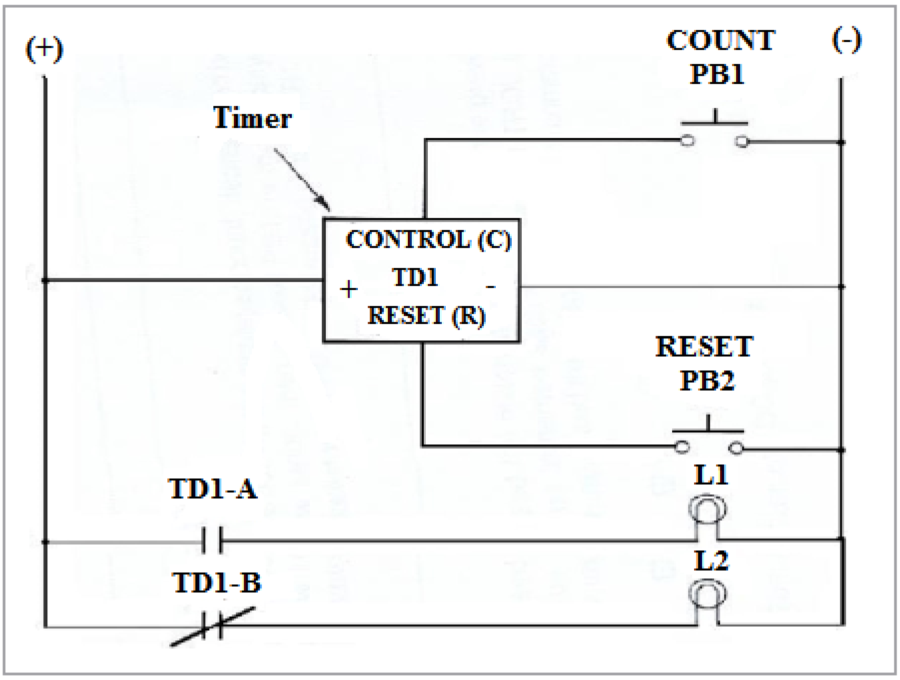
2. The ***"Preset Time"*** switches specify the value *(between 001 and 999)* the timer must reach before the relay contacts are activated (ON-delay operation) or deactivated (OFF-delay operation).

3. The ***"Time Base"*** switch determines the time base. The time base is a measure of the interval counted by the timer.
   - *S ➔ for second.*
   - *M ➔ for minute.*
   - *H ➔ for hour.*

**Experimental Procedure**

**A) Operation of a Time-Delay Relay**

1. Connect the circuit shown in Fig(2). Use the trainer time-delay relay/counter as timer TD1.




**Fig(2):Testing the Operation of a Time-Delay Relay.**

2. On the time-delay relay/counter TD1, set the thumbwheel switches to ***A005S***. This will program the time-delay relay/counter for ON-delay operation, and set the preset time to 5s.
3. Turn on the DC power supply.

➔ Note: When pushbutton PB1 is in the normal (released) condition, control (C) input is deactivated and relay contacts TD1-A and TD1-B are in their normal state.

4. Record the status of the pilot lamps in the appropriate cell in Table(1).
5. What is the timer value shown on the time-delay relay/counter display?

| **Circuit condition** | **Lamp L1** | **Lamp L2** |
|---|---|---|
| Control Input Deactivated | | |
| Immediately after Activation of the Control Input | | |
| 5s after Activation of the Control Input | | |
| After Reset | | |

**Table(1): Lamp Status Versus Coil Condition.**

**Question#1**

Do the pilot lamps change state immediately after the CONTROL input is activated? Or do they change state 5s after the CONTROL input has been activated?

6. Momentarily depress the RESET pushbutton PB2, which will remove the supply voltage at the (+) input of the time-delay relay and will reset the timer value. Do the lamps return to their initial state state when the timer value is reset?

**Question#2**

Based on the data recorded in Table(1), explain how the time-delay relay operates in the ON-delay mode.

7. On the time-delay relay/counter (TD1 ), set the thumbwheel switches to ***B005S*.** This will program the time- delay relay/counter for OFF-delay operation, and set the preset time to 5s.
8. While observing the displayed time and the status of pilot lamps L1and L2, depress pushbutton PB1 momentarily to activate the CONTROL input of time-delay relay TD1.

**Question#3**

Does the pilot lamps change state immediately after the CONTROL input is activated or does they change state 5s after the CONTROL input has been activated?

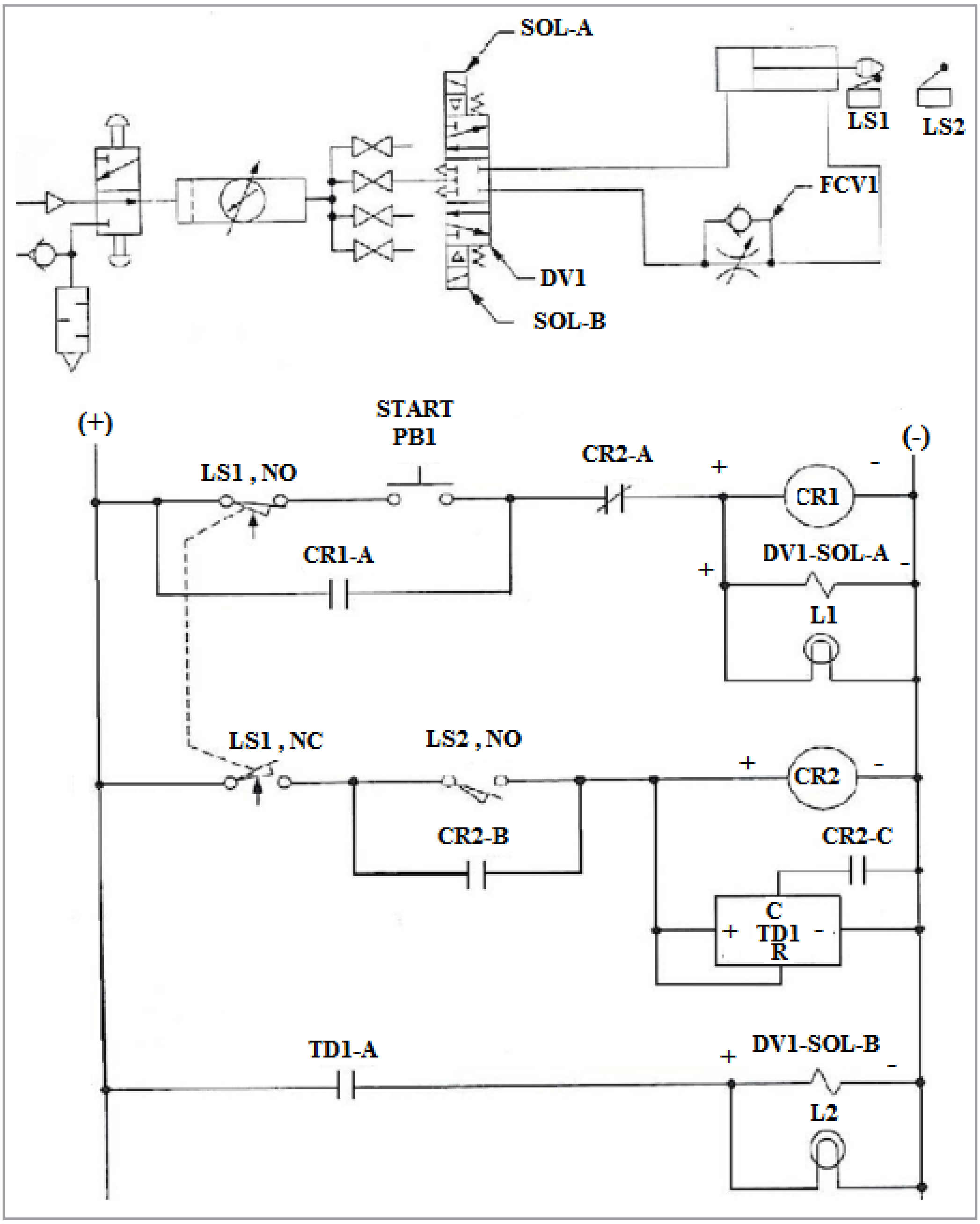
**Question#4**

Based on your observations, explain how the time-delay relay operates in the OFF-delay mode.

9. Turn off the DC power supply, and disconnect your circuit.

## B) Dwell Period Control Using a Time-Delay

1. Connect circuit shown in Fig(3).
2. On the time-delay relay/counter TD1, set the thumbwheel switches to ***A005S***. This will program the time- delay relay/counter for ON-delay operation, and set the preset time to 4 s.
3. Turn on the DC power-supply.
4. Referring to the ladder diagram in Fig(3), describe the operation of the circuit.
5. On the conditioning unit, open the shutoff valves and set the pressure at 300 KPa on the regulated pressure gauge.
6. Start the system by depressing the START pushbutton momentarily.
7. Restart the system several times to become familiar with the operation of the system.




**Fig(3)**

**Question#5**

What causes the cylinder rod to dwell when it becomes fully extended?

**Question#6**

Explain what happens to the dwell period when you increase the pressure.

8. Restart the system several times to observe the dwell period variation.
9. Turn off the DC power-supply.
10. On the conditioning unit, close the shutoff valves, and turn the regulator adjusting knob completely counter clockwise.

**Question#7**

1. What is the difference between an ON-delay and OFF-delay relay?
2. What is meant by "preset time"?
3. What is meant by "cylinder dwell"?

# Part 2: Counters

## Objectives

1. To describe the operation of an electrical counter.
2. To assemble and test a continuous reciprocation system.
3. To extend and retract a cylinder a definite number of times using an electrical counter.
4. To describe the operation of a photoelectric switch.
5. To measure the rotation speed of a motor using an electrical counter.

## Introduction

### Electrical Counters

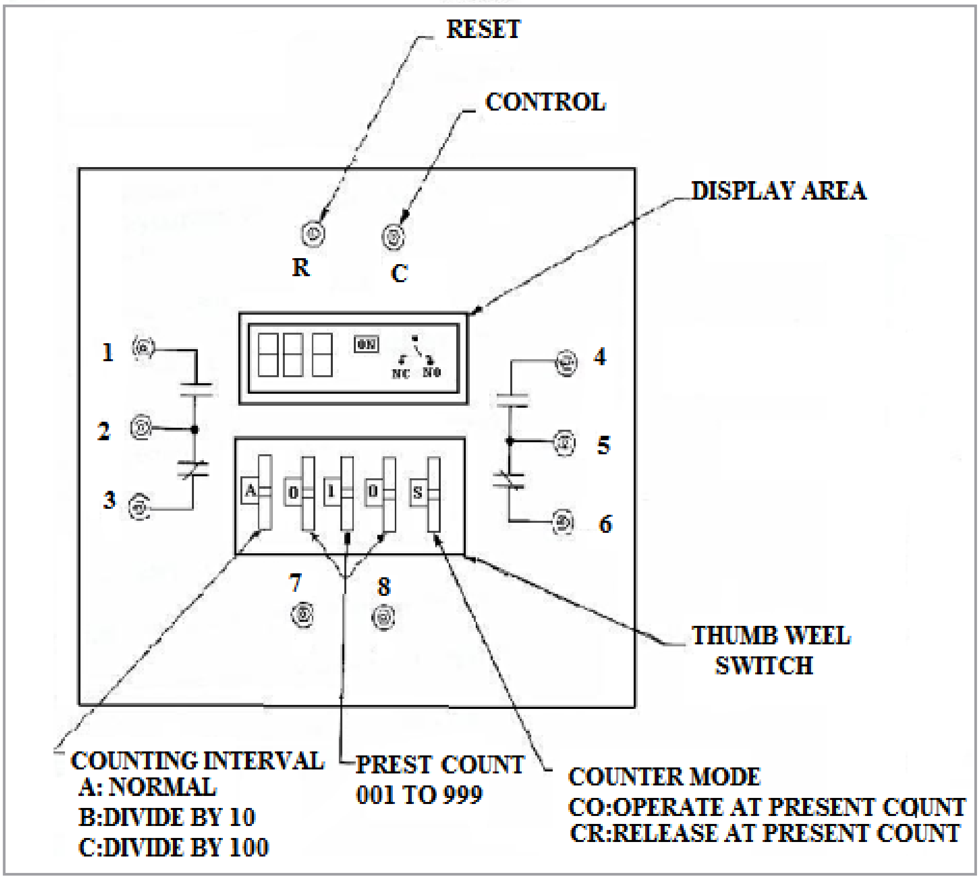
Electrical counters are used in electrically-controlled pneumatic systems when parts of the system must be activated or deactivated after a definite number of events have occurred. They are widely used in industry to count quantities produced during process and control operations. They are also used in machine maintenance scheduling to control the number of machine operations.

A typical application is an automated packaging system that stacks and counts production items into groups. The usual method is for one cylinder to continuously extend and retract, picking and stacking one item on each cycle, and for a counter to count the number of cycles which have been made by the cylinder. When the required count is reached, the counter generates a switching signal which causes another cylinder to push the stack away.

### Pneumatic Trainer Counter

As was said in previously, the time-delay relay/counter supplied with your trainer can be programmed for the counting function by configuring the thumbwheel switches on top of the unit accordingly.

To program the time-delay relay/counter for the counting function, three parameters must be configured: the counting mode, the preset count, and the counting interval, as shown in Fig(4).




**Fig(4):Time-Delay Relay/Counter in Counting Function.**

1. The "***Counter Mode***" switch selects between the following operation modes:

a. *Operate at Preset Count (switch set to CO)*: each time the CONTROL (C) input is switched to common (-) and then disconnected from common, the counter value is incremented by one count. When the preset count is reached, both sets of relay contacts are shifted to their activated state. Additional input pulses continue to increment the displayed count. Momentarily switching the RESET (R) input to common deactivates the relay contacts and resets the counter value to zero.

b. *Release at Preset Count (switch set to CR)*: momentarily switching the RESET input to common activates the relay contacts. Operation is similar to CO mode except that the relay contacts are deactivated when the preset count is reached.

2. The "***Preset Count***" switches specify the value which the counter must reach before the relay contacts are activated (CO operation) or deactivated (CR operation). Can be set between (*001 and 999).*

3. The "***Counting Interval***" switch selects the interval counted by the counter. Selectable as Normal, Divide by 10, or Divide by 100:

a. *Normal (switch set to A, or D to J)*: the counter value is incremented each time an input signal is received at the CONTROL input.

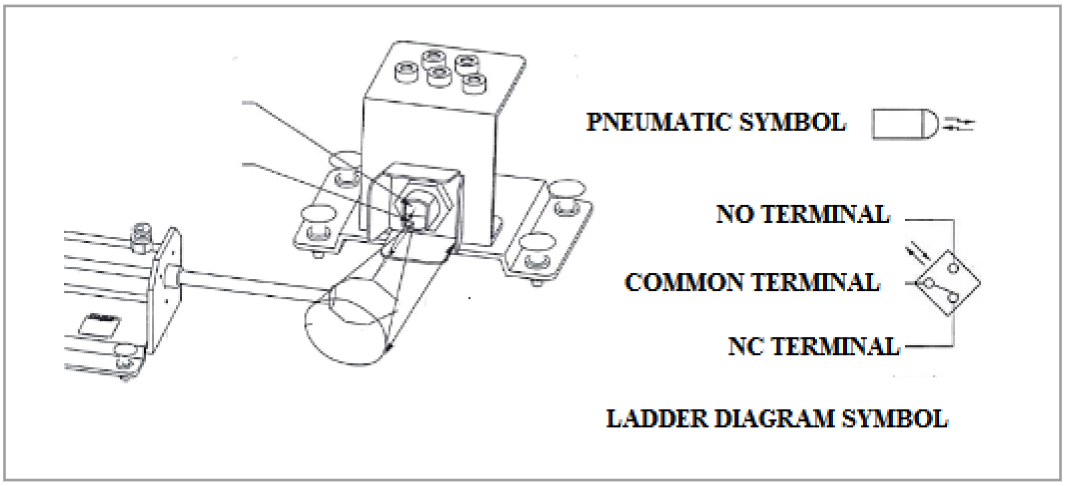
b. *Divide by 10 (switch set to B)*: the counter value is incremented for every 10 input signals for a maximum count of 9990.

c. *Divide by 100 (switch set to C)*: the counter value is incremented for every 100 input signals for a maximum count of 99900.

**Photoelectric Switches**

A photoelectric switch is a sensing element that uses a light beam to sense the presence or motion of an object. Unlike a mechanical limit switch, it can perform these functions without physical contact. Photoelectric switches have several useful applications, including cylinder position sensing, level sensing, product detection and counting, and speed monitoring. The photoelectric switch consists of a light source, a receiver, and one or more sets of NO and NC contacts. The light source and receiver can be in the same casing or separate casings the light source projects a light beam, which may be visible or infrared. The receiver picks up the light from the source, but ignores ambient light.

Fig(5) shows the photoelectric switch supplied with your trainer. This switch is of the proximity type. It consists of a visible light source and a receiver combined in the same casing. When powered by a 24-V dc voltage, the light source projects a beam of red light. When no object is within the detection zone of the switch, the receiver sees dark and keeps the switch contacts deactivated. When a reflective object such as a cylinder rod enters the detection zone, light reflects off the object back to the receiver. This causes the receiver to activate the switch contacts and to keep them activated until the object is removed from the detection zone. A red LED at the rear of the switch indicates the status of the contacts. When it is on, the LED indicates that the switch contacts are activated.




**Fig(5):Photoelectric Switch.**

The trainer photoelectric switch has a detection range of 10.2 cm (4 in), which means that it is able to detect objects located within 10.2 cm (4 in) of it. This range will vary slightly depending upon the reflectance, or ability to reflect light, of objects. The more reflective an object, the farther the detection range. The reflectance of an object depends on its surface material, colour, and texture.

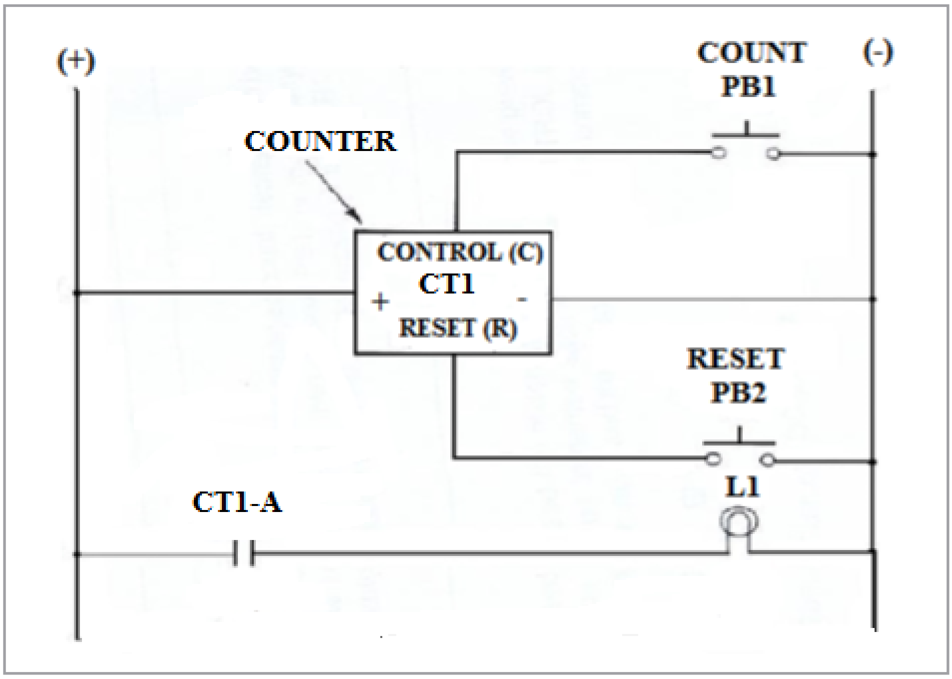
**Procedure Summary**

In the first part of the exercise, you will test the operation of an electrical counter.
In the second part of the exercise, you will connect and test a system that uses an electrical counter to extend and retract a cylinder a definite number of times.
In the third part of the exercise, you will test the operation of a photoelectric switch.
In the fourth part of the exercise, you will use an electrical counter to measure the rotation speed of a pneumatic motor.

## Experimental Procedure

## A) Operation of an Electrical Counter

1. Connect the circuit shown in Fig(6). Use the trainer time-delay relay/counter as counter CT1.




**Fig(6):Testing the Operation of an Electrical Counter.**

2. On the time-delay relay/counter, set the thumbwheel switches to ***(AOO6CO)***, This will program the time-delay relay/counter for the CO (Operate at Preset Count) counting function, set the preset value to 6, and select a normal counting interval.
3. Turn on the Dc power supply.
4. What is the value shown on the time delay relay/counter display?
5. Depress momentarily the COUNT pushbutton PB1. What happens to the displayed count? Why? Explain by referring to the ladder diagram in Fig(6).
6. While observing pilot lamp L1, depress pushbutton PB1 several times until the displayed count reaches the preset value of 6. What happens to lamp L1 when the displayed count reaches 6? Why? Explain by referring to the ladder diagram in Fig(6).
7. Again depress pushbutton PB1 several times while observing the displayed count. Do additional input pulses continue to increment the displayed count?
8. Momentarily depress the RESET pushbutton PB2. What happens to the displayed count? To pilot lamp L1? Why?
9. While observing the displayed count, depress and hold pushbutton PB1 for a few seconds, then release PB1. Is the displayed count incremented immediately when PB1 is depressed or after PB1 is released?
10. Based on the observation you made in the previous step, is the counter value incremented each time the CONTROL (C) input is switched to common (-) and then disconnected from common.
11. Turn off the DC power supply. Disconnect all leads and components.

**B) Counting of Motor Revolutions**

1. Connect the circuit shown in Fig(7). Be careful not to modify the mounting positions of the motor and photoelectric switch.
2. Open the branch shutoff valve number 1 and keep number 2 closed.

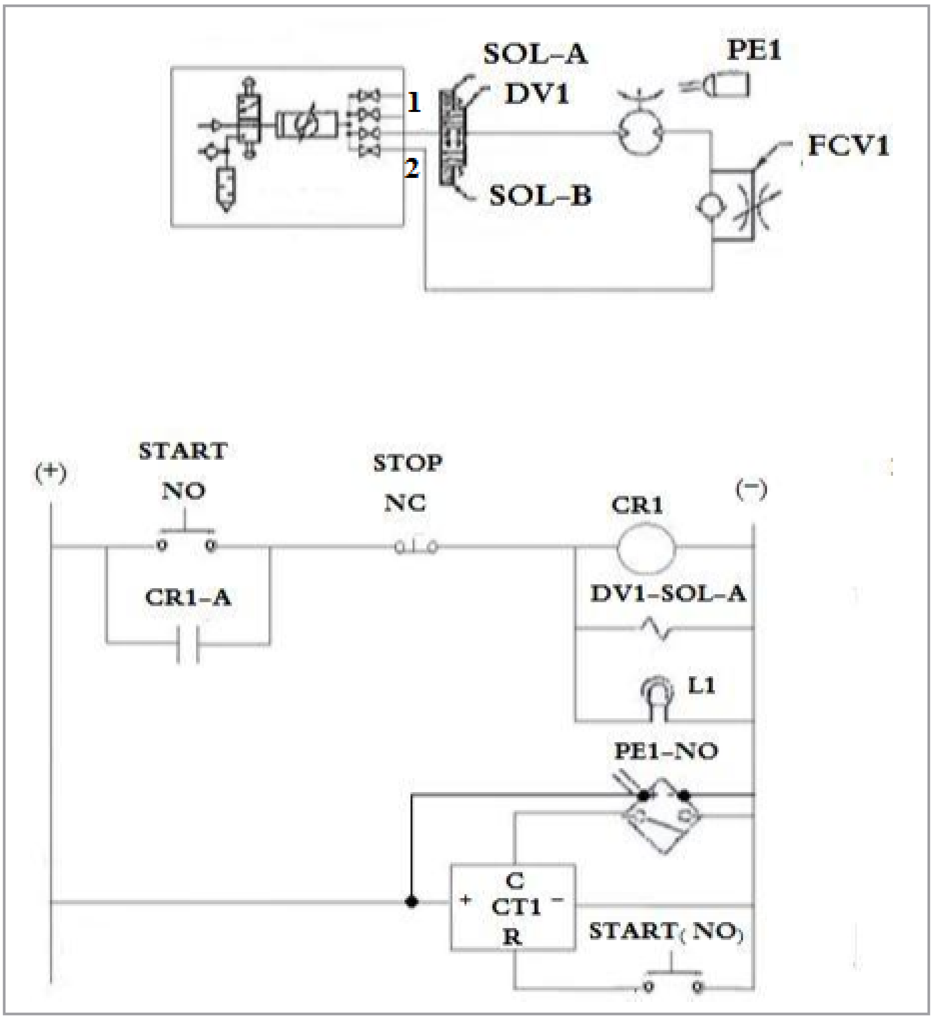



**Fig (7)**

3. On the time-delay relay/counter, set the thumbwheel switches to ***(BOOOCO)***. This will program the time-delay relay/counter for the CO counting function, set the preset value to 0, and select a divide-by-10 counting interval.
4. Open the shutoff valve and the branch shutoff valves at the manifold. Open flow control valve FCV1 by turning the control knob fully counter clockwise.
5. Turn on the DC power supply, and depress the START pushbutton PB1 to energize valve solenoid -A and start the motor. Increase the regulated pressure until the motor tums at a constant speed.

➔ Note: If the LED on the photoelectric switch seems to skip, reduce the rotation speed of the motor by decreasing the air flow with FCV1.

Observe the count value on the time-delay relay/counter display. Since a divide-by-10 counting interval has been selected, the displayed count is incremented by one for every 10 revolutions of the motor. Multiply the displayed count by 10 to obtain the motor speed, in revolutions per minute *(r/min)*. Record the motor speed.

6. Using a stop watch, measure the rotation speed of the motor by performing the following steps.
    a. Depress the RESET push button PB3,and simultaneously start the stop watch.
    b. Let the motor turn for 60s,then stop the motor by depressing the stop pushbutton PB2.

7. Again depress pushbutton PB1 to start the motor. Place a tachometer on the motor shaft and measure the motor speed. Does this speed approximately correspond to the speed recorded in the previous step?
8. Turn off the DC power-supply.
9. On the conditioning unit, close the shutoff valves, and turn the regulator adjusting knob completely counter clockwise.

# Electrical Engineering Department
# Control Lab
# Experiment #11
# Traffic Light simulation on PLC

**Objectives**

To use PLC for traffic light simulation as an application.

**Introduction**

The equipment simulates the traffic signal operation in 4-roads crossing. The different components of the electrical circuit to be controlled by PLC are mounted on a Bakelite silk-screen-printed panel, with the relative signalizations and commands.

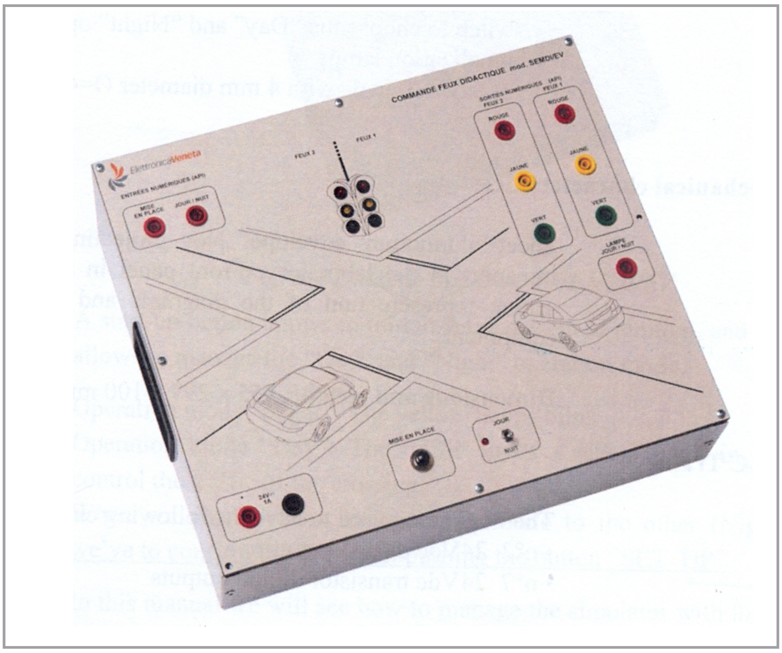
All the signalization lamps are connected in an independent way to a terminal box composed by safety terminals, so that we can choose the type of connections between the different components and the PLC depending on the management operation mode.

A start-up button allows to initialize the system at ignition, and a switch allows to manage the ‘‘Day’’ and ‘‘Night” operation mode.

Electrical characteristic:

- 1 start-up button.
- switch to choose the ‘‘Day’’ and ‘‘Night” operation mode.
- 6 signalization lamps.
- 11 safety terminals.

Fig(1) shows traffic light panel.

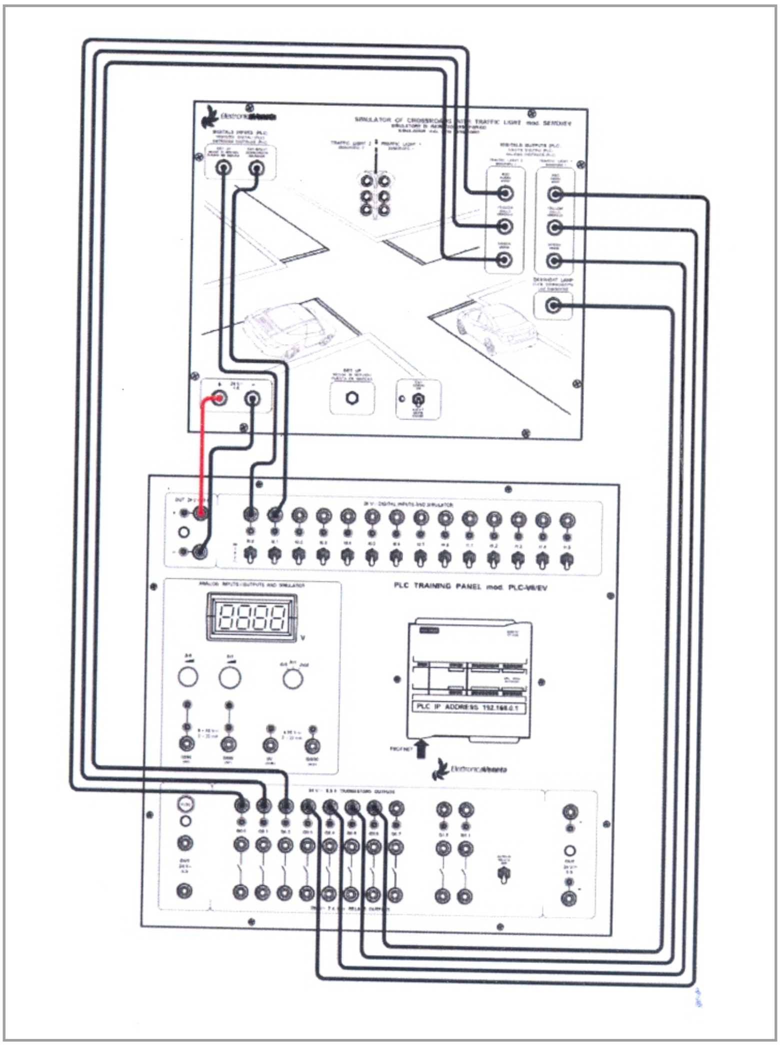


**Fig(1)**

A start-up button allows to initialize the system at ignition, and a switch allows to manage the ‘‘Day’’ and ‘‘Night” operation mode.
Operation mode ‘‘Night”: The yellow lamps blink.
Operation mode ‘‘Day’’: The traffic lights 1 and 2 work in order to control the traffic of the crossing.
When we change from an operation mode to the other (Night /Day).
<u>We have to confirm the operation pushing the button ‘‘SET UP”</u>

## **<u>Experimental procedure</u>**

Connect the circuit as shown in Fig(2).



**Fig(2)**

***Note:***
***<u>The code and operation steps will be provided by your instructor.</u>***

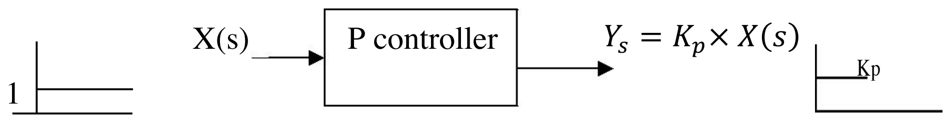
# Electrical Engineering Department
# Control Lab
# Experiment #12
# Types of Controller

**Objectives**
To study the deferent types of controllers P, PI, PD.

**Introduction**
There are several types of controllers as follows:

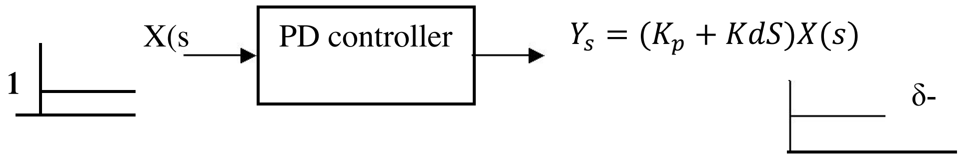
1. Proportional controller $K_p$

$Y_s = K_p \times X(s)$ where $K_p$ is constant.



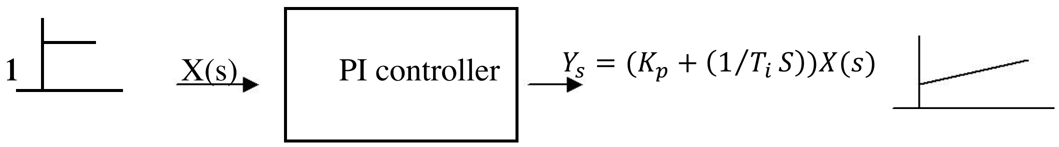

2. PD controller

$Y_s = (K_p + KdS)X(s)$




3. PI controller

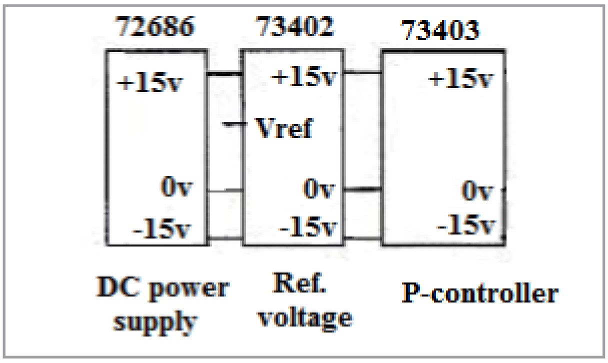
$Y_s = (K_p + (1/T_i\,S))X(s)$



## Experimental procedure

### A) P-controller

a. Connect the circuit as shown in Fig(1).




**Fig(1)**

b. Set the reference variable voltage to (***1 volt)*** and $K_p$ as in Table(1).

| $K_p$ | Final output | Draw output |
|---|---|---|
| $0.1 * 2.0$ | | |
| $1 * 4.0$ | | |
| $10 * 1.0$ | | |

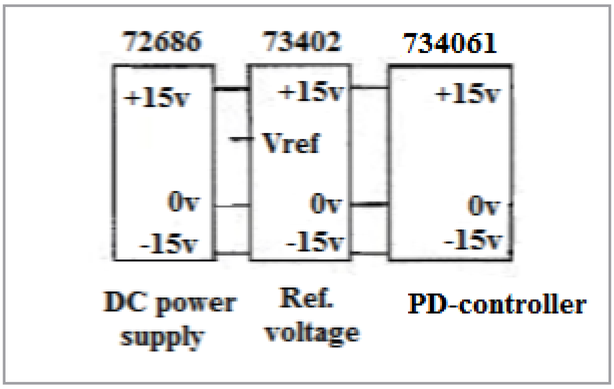
**Table (1)**

### Question#1

Calculate $K_p$ from $V_o/V_{in}$ and compare the calculated value to input $K_p$ from controller.

### B) PD controller

1. Connect the circuit as shown in Fig(2).




**Fig(2)**

2. Set $K_p$ to ***(1)*** and $T_v$ to **(1×0.1)** and $V_{in}$ to ***(1volt)***, then read the value of the output, tabulate your results in Table(2).

| $K_p$ | $T_v$ | $V_{in}$ | $V_{out}$ (Draw) |
|---|---|---|---|
| 1 | 1×0.1 | 1 | |
| 1 | 1×0.1 | 2 | |
| 1 | 1×0.1 | 3 | |
| 1 | 1×0.1 | 4 | |
| 1 | 1×0.1 | 5 | |

**Table(2)**

**Question#2**

How does the changes of $V_{in}$ effect to the output.

**C) PI controller**

In part B change PD controller to PI controller and tabulate your result as in Table(3).

| $K_p$ | $T_n$ | $V_{in}$ | $V_{out}$,ts(Draw) |
|---|---|---|---|
| 2×0.1 | 1×0.1 | 1 | |
| 2×0.1 | 1×0.1 | 1.5 | |
| 2×0.1 | 1×0.1 | 2 | |
| 2×0.1 | 1×0.1 | 2.5 | |
| 2×0.1 | 1×0.1 | 3 | |

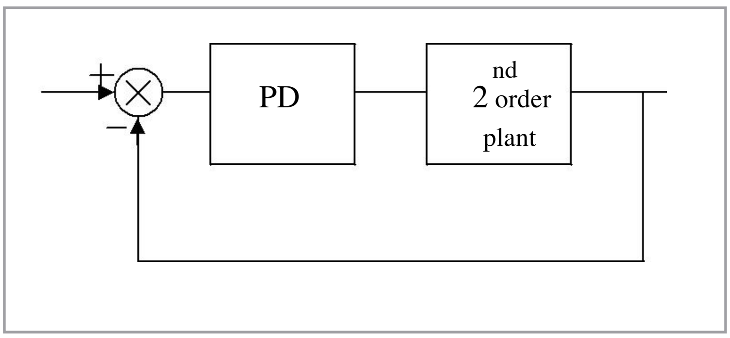
**Table(3)**

**Question#3**

How does the changes of $V_{in}$ effect to the output.

**D) Effect of PD controller on second order plant**

1. Connect the circuit shown below.
2. Adjust the second order system to: Damping coefficient $\boldsymbol{\zeta = 0.5}$ and $\boldsymbol{T = 0.2 \times 1}$.
3. Set the parameter in PD controller as in Table(4) below. Sketch the output and tabulate your results.



| $K_p$ | $T_v$ | $V_{in}$ | $V_{out}$ |
|---|---|---|---|
| 1 | 0.5×0.1 | 1 | |
| 1 | 0.5×1 | 1 | |
| 1 | 0.5×10 | 1 | |
| 2 | 1×0.1 | 1 | |
| 3 | 1×0.1 | 1 | |

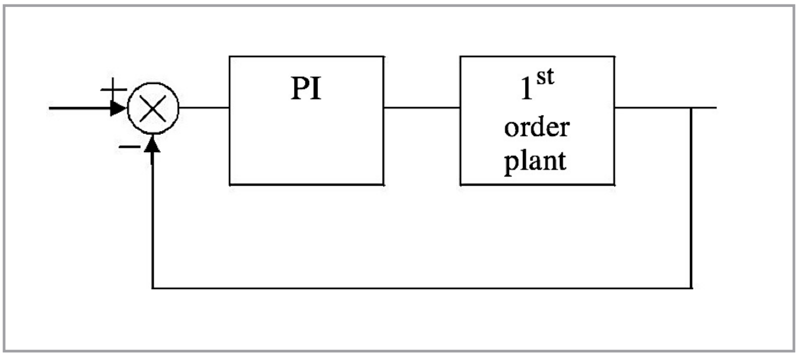
**Table(4)**

**Question#4**

1. How does the changes of the value of $T_v$ effect to the output.
2. How does the changes of the value of $K_p$ effect to the output.

**E) Effect of PI controller on first order plant**

1. Connect the circuit shown below.
2. Adjust the first order system to: $\boldsymbol{K_s = 0.6}$ and $\boldsymbol{T = 2.}$
3. Set the parameter in PI controller as in Table(5) below. Sketch the output and tabulate your results.



| $K_p$ | $T_n$ | $V_{in}$ | $V_{out}$ (Draw) |
|---|---|---|---|
| 1 | 5×0.1 | 1 | |
| 1 | 10×0.1 | 1 | |
| 1 | 5×1 | 1 | |
| 1 | 10×0.1 | 1 | |
| 2 | 10×0.1 | 1 | |
| 3 | 10×0.1 | 1 | |

**Table(5)**

**Question#5**

1. How does the changes of the value of $T_n$ effect to the output.
2. How does the changes of the value of $K_p$ effect to the output.